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FUEL ASSEMBLY DESIGN STUDY FOR THE TUNGSTEN WATER-MODERATED REACTOR (TWMR)[U]

by

T H Cox, R K Giertsen, E Guenther, Jr,
S Kaufman, F A Schumann, and J T Trushin

prepared for

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FINAL REPORT

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by

I H Cox, R K Giertsen, E Guenther, Jr,
S Kaufman, F A Schumann, and J T Trushin

prepared for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

August 31, 1966

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Technical Management
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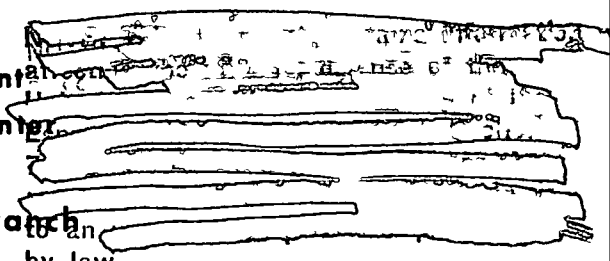

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FOREWORD

This is the final technical report submitted to the Lewis Research Center, Chemical and Nuclear Rocket Procurement Section, National Aeronautics and Space Administration, Cleveland, Ohio, under Contract NAS 3-7984 It presents the work accomplished by the Martin Company Nuclear Programs, on the Design Study of Fuel Element Assemblies for the Tungsten Water-Moderated Reactor (TWMR) for the period June 29, 1965 through March 31, 1966

The report was classified in accordance with DD Form 254-1 dated July 1, 1965 and the Joint Classification Guide for Nuclear Rocket Propulsion Systems (ROVER) (CG-RR-2)

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ABSTRACT

A design study of the TWMR fuel assembly was performed under NASA Contract NAS 3-7984 A reference design configuration and alternate concepts for each of the major design areas were created

Supporting thermal and stress analyses were completed for individual components A multidegree of freedom vibration analysis technique was correlated with a NASA experiment and used to predict the general requirements for lateral support of a TWMR fuel assembly

Development recommendations are presented for continuation of the vibration analysis work to predict a final design lateral support system

The publication of this technical report does not constitute NASA approval of the Martin Company findings or conclusions It is published only for the exchange and stimulation of ideas

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I INTRODUCTION

This design study was initiated for the purpose of investigating fuel assembly configurations for the tungsten water-moderated reactor (TWMR) This concept is being investigated by the Lewis Research Center of NASA for possible application in nuclear rocket systems The specific assignment was to create and analyze conceptual design solutions to the major problem areas involved

The TWMR core is contained in a cylindrical aluminum pressure vessel The cylinder is closed at each end by a flat tube sheet with two-inch diameter cylindrical aluminum tubes in a hexagonal array extending between and fastened to each of the tube sheets Figure 1 shows the general arrangement at the location of one of the two-inch diameter aluminum pressure tubes The region outside of the aluminum pressure tube is filled with flowing pressurized water which acts as the reactor moderator and structural member coolant The fuel element assembly is positioned within the pressure tube

The fuel assembly channels hydrogen propellant flow over the fuel stages supported and aligned within the primary structural member of the fuel assembly, the support tube This support tube is necessary to provide a separator between the hot flowing propellant and an insulating layer of stagnant hydrogen established between the fuel assembly and the aluminum pressure tube A cold end seal between the pressure tube and the fuel assembly support tube prevents propellant leakage through the insulation space

Primary loads on the individual fuel stages within the support tube are the axial aerodynamic loads caused by the high velocity propellant flow These loads are carried to the reactor structure by the support tube which is anchored to the reactor pressure shell at the inlet end Secondary lateral loads on the fuel stages and support tube, caused by vibration or maneuvering acceleration, must be reacted between the support and aluminum pressure tubes to prevent their contact during operation

All structural design efforts must be considerate of the fact that the TWMR is a moderated reactor in which nonfuel bearing materials must have a minimum total thermal neutron absorption For this reason, as well as to minimize the weight of a device intended for deep space flight, total structural mass must be efficiently utilized

The overall design task is considered to key on five related problem areas

(1) Inlet end--the cold end gas seal, attachment of the fuel assembly to the inlet tube sheet, and the inlet reflector configuration and support

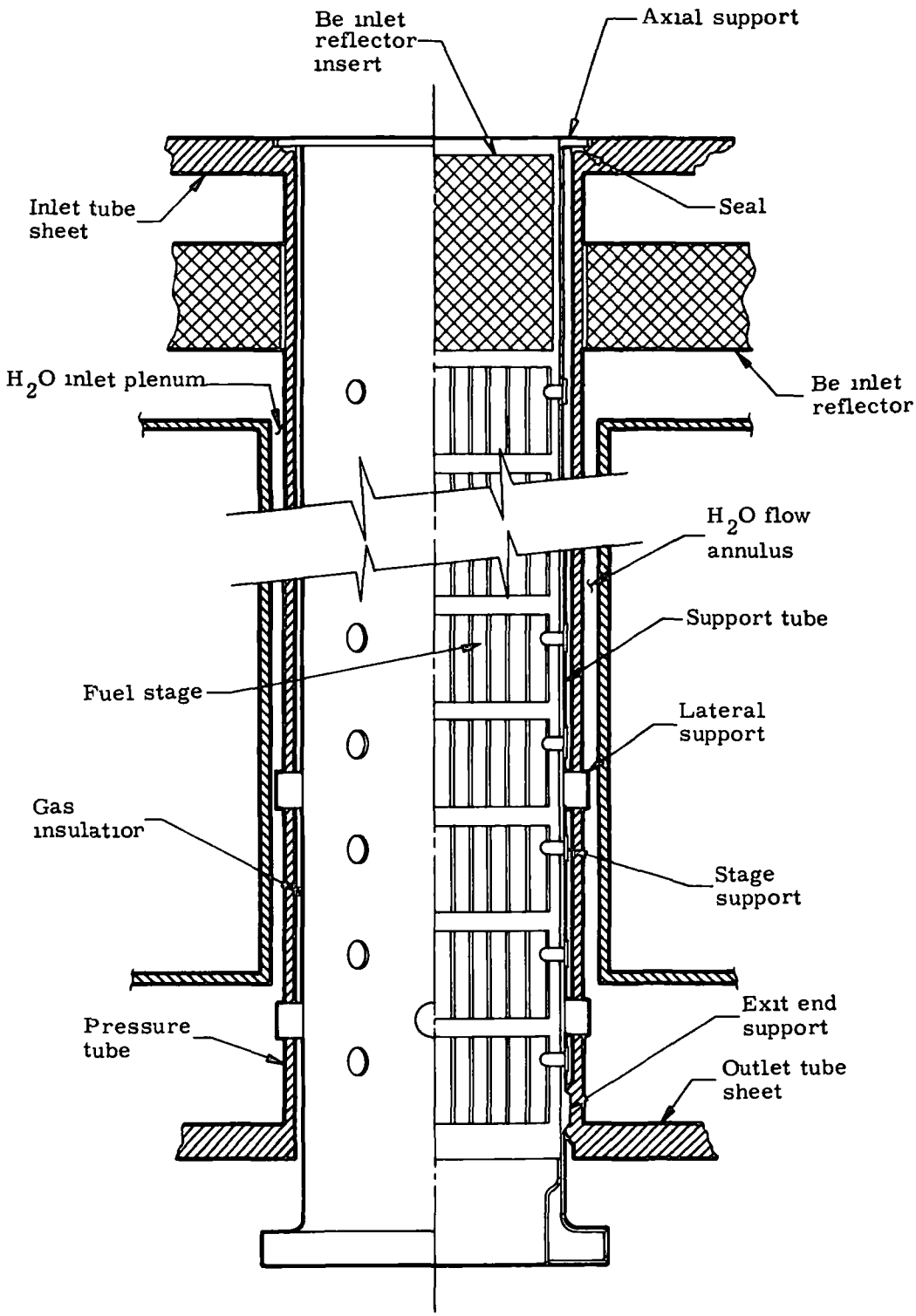

Fig 1 Schematic Arrangement, TWMR Fuel Assembly

(2) Support tube--construction method of the composite material tube, local stresses due to lateral support devices, and stresses due to axial temperature gradient and/or temperature discontinuities

(3) Fuel stage support--support and alignment within the support tube in the presence of high temperatures and high thermal gradients

(4) Exit end--provision of sufficient insulation between core exit gases and aluminum exit tube sheet, lateral support between support and pressure tubes

(5) Lateral support--design of support devices and selection of their number and location on support tube

These areas were each considered during the course of contract work The resulting designs and supporting analyses are presented in this report

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II SUMMARY

This final technical report describes the work accomplished by the Nuclear Products Group of the Martin Company during the period from June 29, 1965 through March 31, 1966, in accordance with NASA Contract NAS 3-7984 Monthly progress reports issued under this program include MND-3231-1 through -7

The overall scope of effort for this program consisted of

(1) Preparation of mechanical design drawings of fuel assemblies in sufficient detail to indicate geometry, dimensions, fabrication and assembly techniques, and materials of construction

(2) Performance of stress and vibration analyses for the reference design

(3) Performance of heat transfer analyses for those operating conditions leading to a determination of overall heat transfer characteristics and the temperature distributions necessary to calculate worst case stress conditions

Specific accomplishments of this program and conclusions concerning major questions include

(1) Preliminary design of a TWMR fuel assembly (Fig 6) was completed, with the exception of the lateral support system details The fuel stages are pin-supported, the support tube is a composite columbium-molybdenum-tungsten tube, and a multileaved cantilever spring inlet end connection is used for remote assembly from the reactor aft end

(2) A computer code technique for analyzing the lateral support system vibration response to flight vibration inputs was checked with good correlation against a NASA experimental mockup This technique was then used to briefly investigate several nonoptimum systems It appears quite certain that the aluminum pressure tube must be stiffened during final design evolution It is also evident that the lateral support system design can be accomplished and reasonable stress levels maintained

(3) Thermal analyses verifying the feasibility of several unique spring support devices was completed These spring plunger supports operate at spring maximum temperatures of about 1300° F, offering reliable, long term service even in the 4000° F exit end environment

These investigations and associated supporting work are described in Chapters III through V

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III ASSEMBLY DESIGN

The completed contract effort has resulted in the development of a specific reference design concept with alternatives for each major design area, with the exception of the lateral support system This most complex design area was studied extensively with the result that an analytical technique for the comparison of various lateral support systems was established, correlated with a NASA experimental mockup assembly, and applied to a few specific reference designs to obtain an initial feasibility evaluation

Presented in this section of the report are the applicable design criteria and constraints against which all designs must be evaluated, along with a description of the chosen reference design and associated alternate concepts A final portion presents and discusses the engineering analyses performed during the design development

A DESIGN CRITERIA

1 Mechanical

The structural system shown in Fig 1 must withstand intense static and vibratory loading throughout the booster-powered flight and nuclear rocket operational phases In most cases, the reactor operating condition is more severe due to the extremely high temperature environment The load and thermal environments are as follows

a Booster-powered flight

(1) No pressure differential across support tube

(2) Temperature of support tube and fuel stages = 70° F

(3) Sustained or static loading

(a) -5 g longitudinal or along the axis

(b) ±1 g lateral or transverse

(4) Vibration load input, not including the dynamic response of the structure or resulting load amplification (see Fig 2)

(a) ±5 g at 87 to 2000 cps longitudinal

(b) ±1 g at 12 to 500 cps lateral

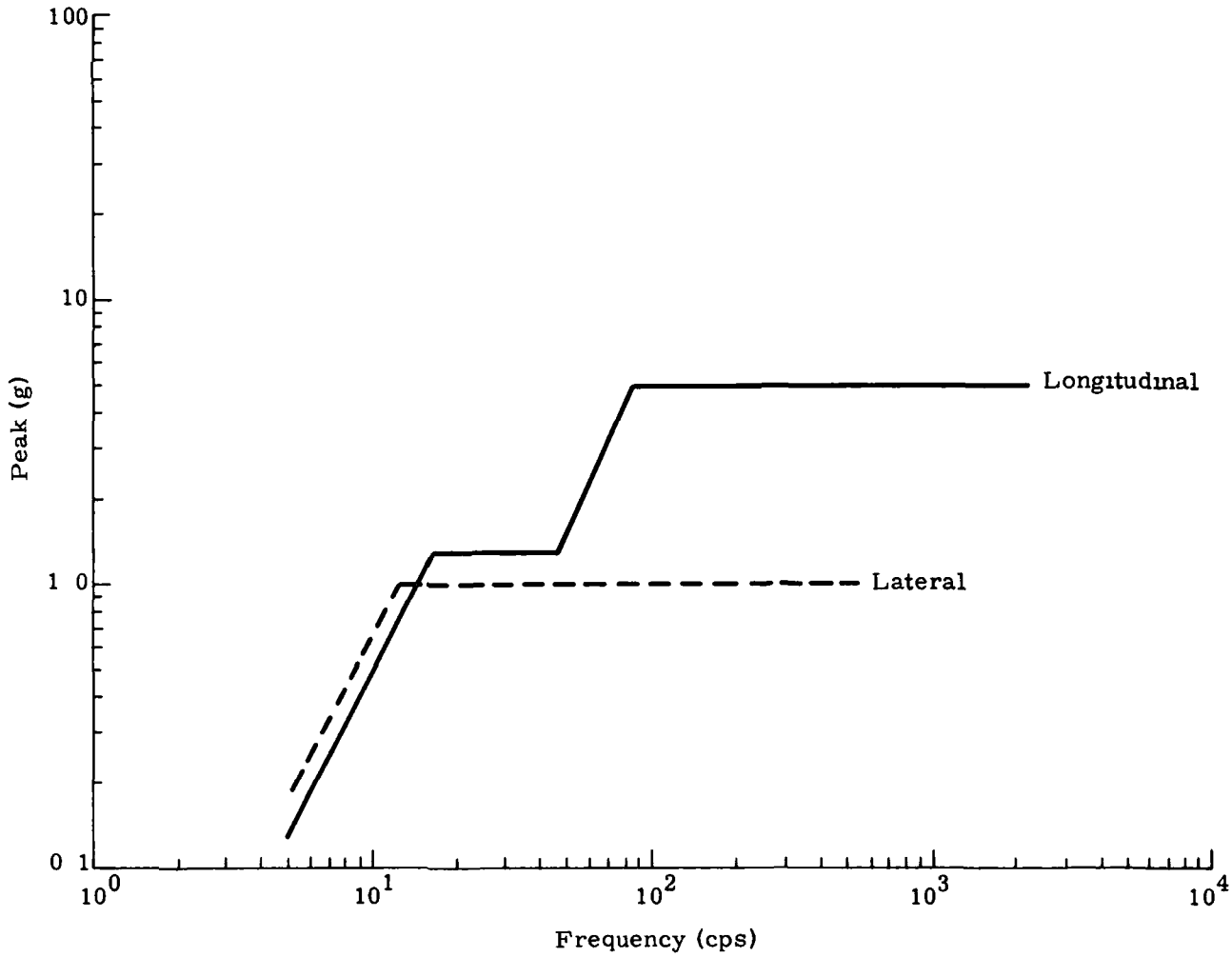

Fig 2 Vibration Acceleration as a Function of Vibration Frequency

b Operational phase

(1) Pressure differential across the support tube is 105 psi at the inlet tube sheet and 0 psi at the exit end, with a linear distribution assumed

(2) Support tube temperature is -138° F at the inlet end and approximately 4000° F at the exit end. The distribution will be calculated The maximum fuel stage temperature will be conservatively considered as 4000° F

(3) Sustained loads

(a) 0 to +2 g longitudinal

(b) ±1 g lateral

(4) Vibrational loads--same as the booster-powered flight phase

The following stress criteria were chosen for evaluating stresses developed by the two different loading conditions Little difficulty is encountered in meeting these criteria during the boost phase since high material strengths are available at the relatively low temperature involved For the boost phase, the criteria are as follows

80% of yield strength for ductile materials

25% of ultimate strength for brittle materials

50% of critical buckling stress

Brittle material will be defined as a material which fails under a uniaxial tension test with a total strain of 0 5% or less Since stress distribution in a structure is seldom uniaxial, the "equivalent" stress for a brittle material will be the absolute value of the highest principal stress

For ductile materials, the equivalent stress will be derived via the Mises criteria,

$$\sigma_o = \sqrt{\frac{1}{2}\left[(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2\right]}$$

where

σ_o = equivalent stress

σ_i = principal stresses

i = 1, 2, 3

To evaluate the operational phase, more detailed criteria are required as a result of the very high temperatures encountered and the desired operational life Two categories of criteria are proposed to cover both steady-state and fatigue stress environments The steady-state condition is defined as the total operational stress state less thermal stresses, stress concentrations and stresses induced from the vibration response Creep stress is in this steady-state category, since by definition, creep is considered as a constant stress state resulting in a time-dependent strain history

Design allowable steady-state stresses are

80% of yield stress

33% of buckling stress

20-hour stress rupture stress

Bearing stress and pure shear will be considered to have the same stress rupture limitation as tension For bearing loads, this is almost certainly conservative, for shear some question exists, but the stated assumptions, while arbitrary, must in any event be checked by prototype component test under actual operating conditions

The final phase of the operational stress evaluation will incorporate the vibratory loads and thermal stresses A conservative approach will be to assume a required infinite life on a fatigue basis The limiting allowance will be the material endurance limit taken as 60% of the yield strength at temperature until a more precise value can be obtained from experiments or the literature Fatigue evaluation, by means of a modified Goodman diagram, is proposed where the mean stress is plotted as the abscissa and alternating stress amplitude is plotted as the ordinate A stress envelope is established by drawing a straight line between the endurance limit on the vertical axis and the ultimate strength on the horizontal axis

2 Thermal

Thermal analysis is critically important to the complete engineering analysis of certain design areas These areas include the lateral support devices, beryllium inlet reflector plug and the fuel stage inlet comb Analysis is also required to generate temperature distributions for use in stress analyses of such components as the lateral support devices and the assembly support tube

Certain starting criteria and data were supplied by NASA-Lewis at the start of the contract These are listed under the pertinent investigative areas

The machine printout of a computer code calculating heat transfer and propellant flow characteristics for an assembly made up of concentric ring fuel stages was provided, as well as a graph summarizing the code printout This graph is shown in Fig 3 Propellant data were used in determining propellant temperatures and heat transfer coefficients for input to the Martin TIGAMM* code when calculating the temperature distribution in the support tube Nuclear fuel power densities (which actually were input to, rather than output from, the NASA code) were used in determining the two-dimensional temperature distribution in the inlet fuel stage Pressure drop data were used to determine the total aerodynamic drag force on individual fuel stages and the overall fuel assembly

Data were also supplied for the moderator water flowing outside the aluminum pressure tubes A constant water temperature of 240° F was used as well as a constant heat transfer coefficient of 4000 Btu/hr-ft^2-°F between the water and the aluminum pressure tube

Internal heat generation rates in nonfuel-bearing materials within the TWMR reactor were supplied as a function of axial position within the reactor These data are shown in Figs 4 and 5

3 Spatial

The overall assembly dimensional envelope is controlled by installation in the TWMR reactor as shown in Ref 1 A primary constraint on fuel assembly geometry is the distance between fuel assemblies This limits the maximum wall thickness and outer diameter configuration of the aluminum pressure tube The minimum pressure tube wall thickness was given as 0 060 inch to withstand a 100 psi external pressure at 300° F with a factor of safety on critical buckling of three

A plenum for distribution of a chemical poison solution control system is located several inches above the inlet tube sheet This precludes loading of the fuel assembly from the inlet end It is assumed that small fastening devices can be installed and tightened from the inlet end

The axial, lateral and stage support structures must be designed to minimize the associated thermal neutron absorption, and also to minimize the effect of these structures on average exit gas temperature

* This is a revised version of the TIGER-II code described in KAPL-2044, May 29, 1959, by Bray and McCracken

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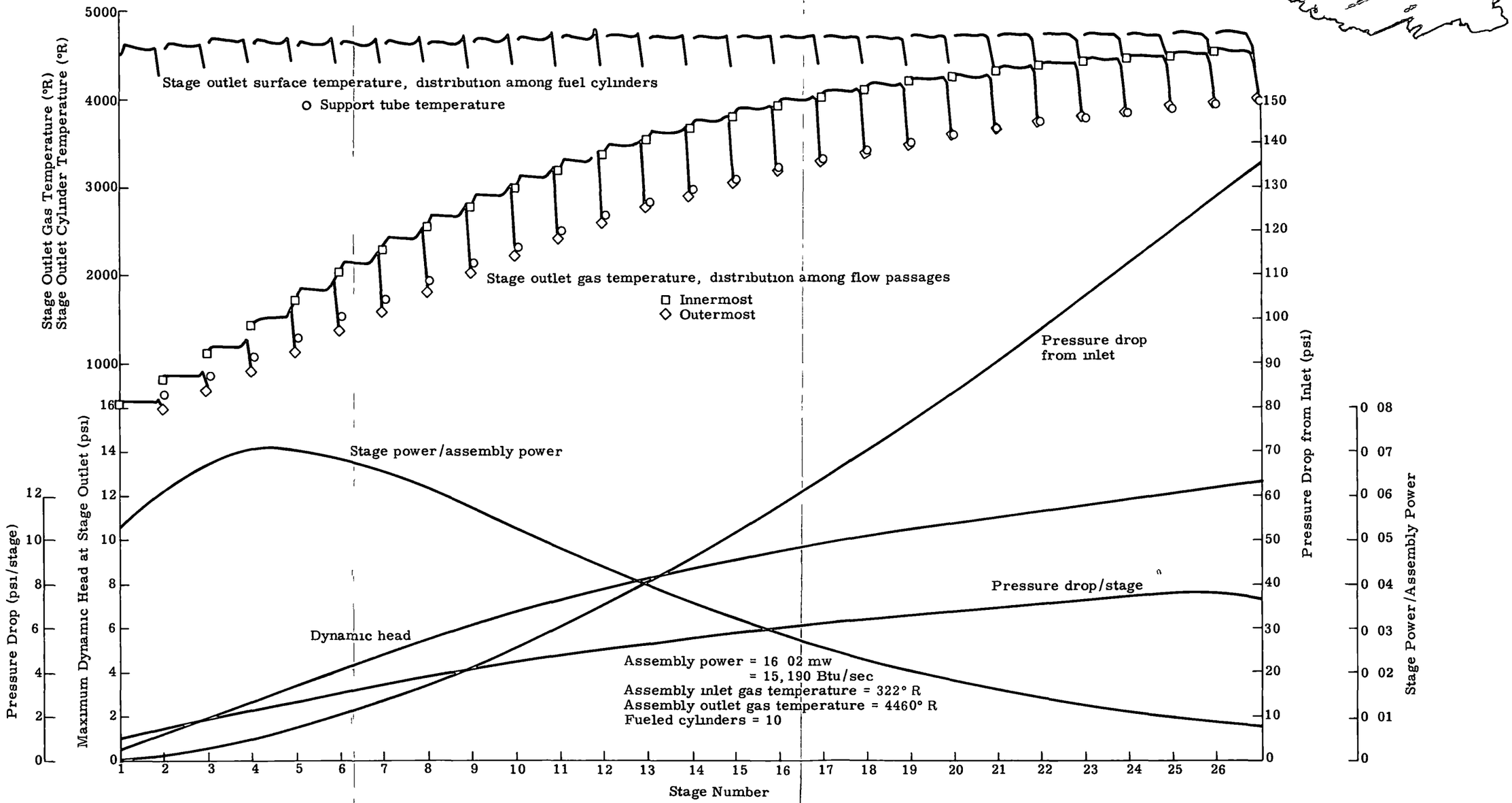
Stage Outlet Gas Temperature (°R)
Stage Outlet Cylinder Temperature (°R)
Stage outlet surface temperature, distribution among fuel cylinders
Support tube temperature
Stage outlet gas temperature, distribution among flow passages
Innermost
Outermost
Pressure drop from inlet
Stage power/assembly power
Pressure drop/stage
Dynamic head
Assembly power = 16 02 mw
= 15,190 Btu/sec
Assembly inlet gas temperature = 322° R
Assembly outlet gas temperature = 4460° R
Fueled cylinders = 10
Pressure Drop (psi/stage)
Maximum Dynamic Head at Stage Outlet (psi)
Pressure Drop from Inlet (psi)
Stage Power/Assembly Power
Stage Number

Fig 3 Heat Transfer and Flow Calculation Results for Assembly of Concentric Fueled Cylinders

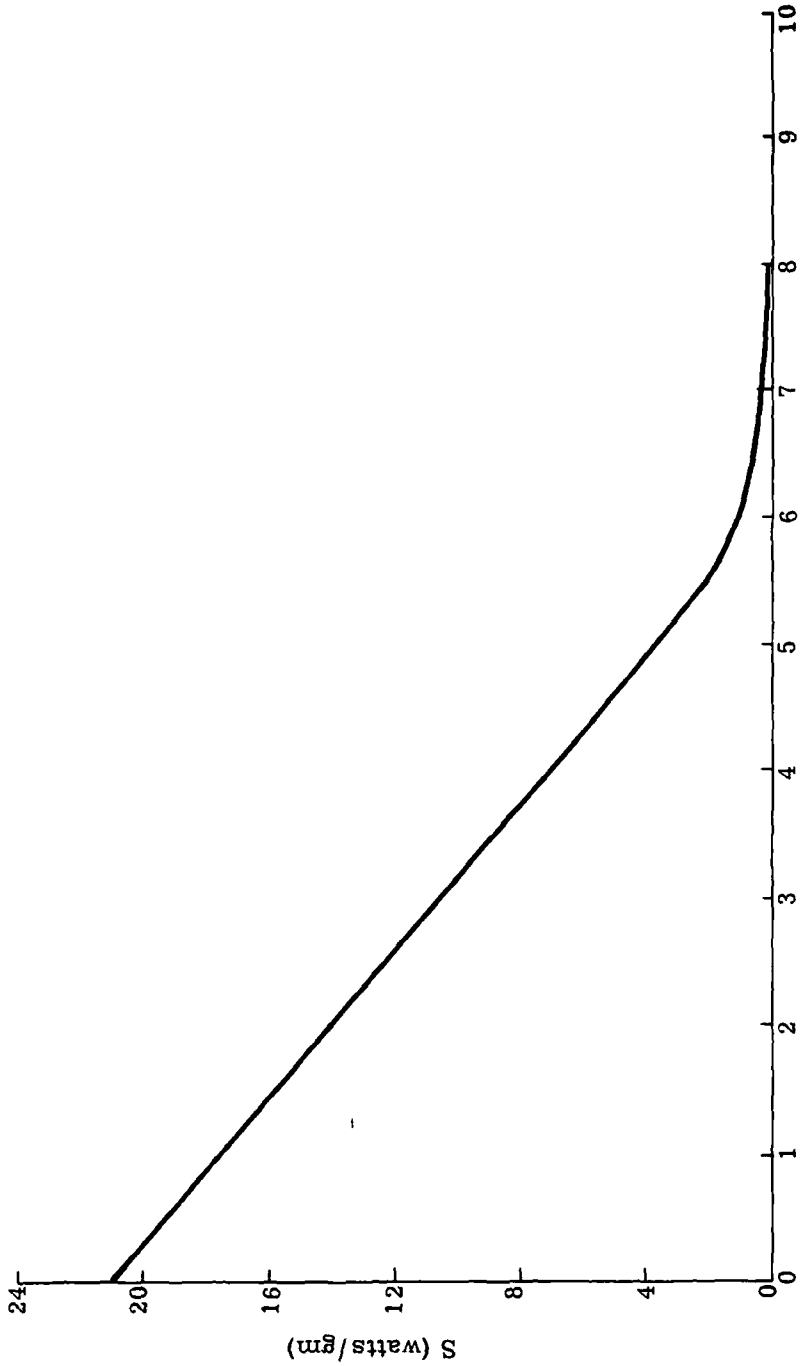

Fig 4 Heat Generation in Aluminum as a Function of Location Above TMMR Active Core

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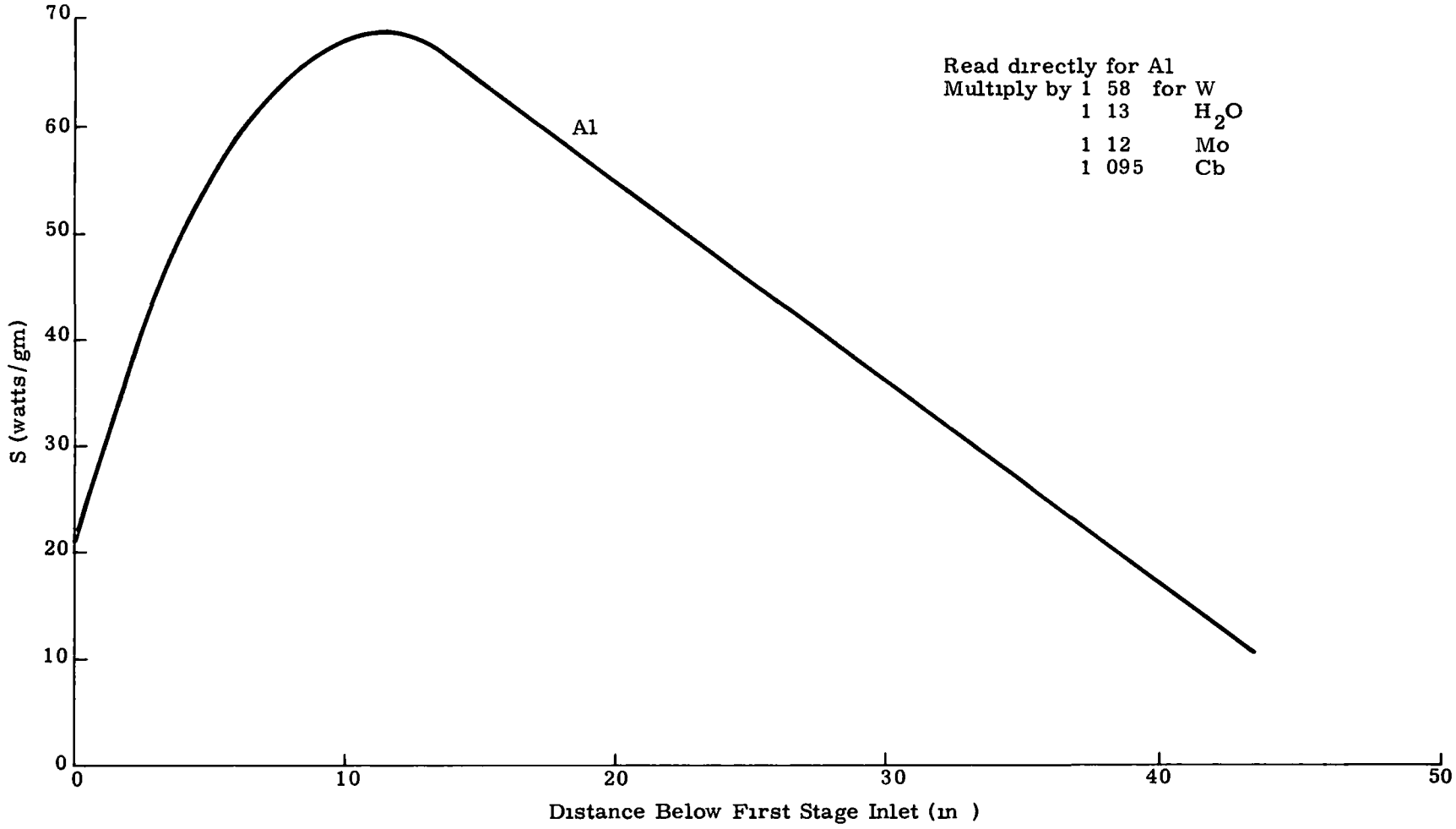

Fig 5 Heat Generation in Materials as a Function of Location Within TWMR Active Core

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B DESIGN DESCRIPTION

1 General

The fuel assembly is essentially a composite refractory metal support tube containing 26 separate but dimensionally identical fuel stages and a beryllium inlet reflector plug The reference design assembly is shown in Fig 6 Alternate concepts are shown in Fig 7

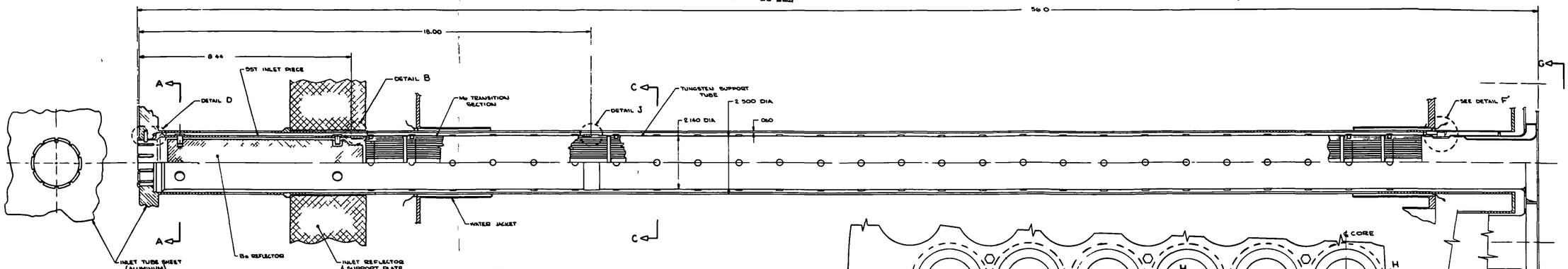
Fuel stages are pinned to the support tube wall and the support tube is attached to the reactor inlet tube sheet The aluminum pressure tube welded into the tube sheet at each fuel assembly location carries axial aerodynamic loads from the support tube to a heavy beryllium inlet reflector plate This plate transfers the load to the reactor pressure shell

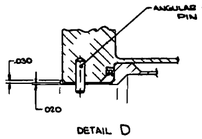
The fuel assembly support tube positions and aligns the fuel stages within its diameter, and provides a gas-tight liner separating the high velocity propellant flow from a stagnant hydrogen insulating layer in the annular space between the concentric support and pressure tubes The support tube attachment at the inlet tube sheet also incorporates a gas seal to prevent excessive propellant leakage through the annular gas space

Mechanical loads due to lateral accelerations require lateral support devices along the 56-inch long, 2 14-inch diameter support tube These support devices and their locations on the support tube comprise the major design problem area of the TWMR fuel assembly Detailed design of the lateral support system requires an iterative multidegree of freedom vibration analysis, the techniques for which have been developed under this program Springs have been utilized as support devices Their rates (reactive force per unit deflection) and chosen locations on the support tube have been used in digital computer analyses to predict bending stress levels in both the support and pressure tubes as a function of time and axial position

A special support is utilized between support and pressure tubes at the exit end of the fuel assembly This support permits radial and axial thermal expansion while preventing lateral deflection under steady-state or vibratory loading This approach results in lower stresses than using a spring device in the same location Thus the total support tube interaction with the adjacent reactor structure is analogous to that of a tubular beam fixed at the inlet end, simply supported at the exit end, and simply supported on elastic supports at a number of places between inlet and exit ends

Design conclusions derived from this study are





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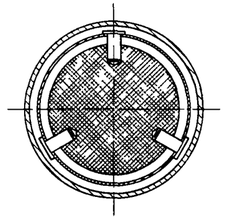

SECTION A-A
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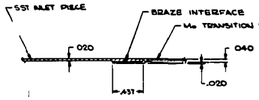

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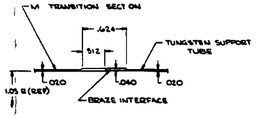

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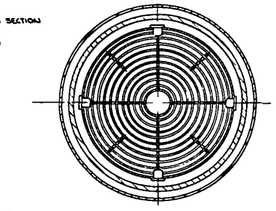

SECTION C-C
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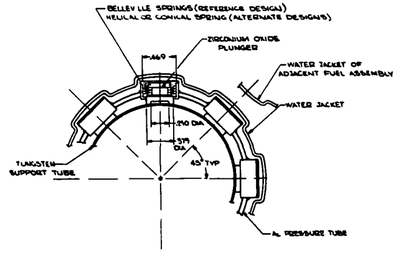
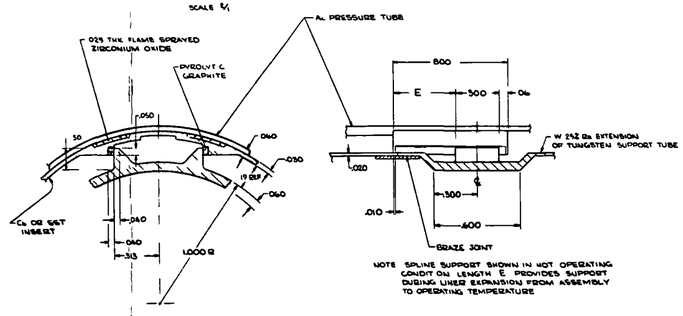
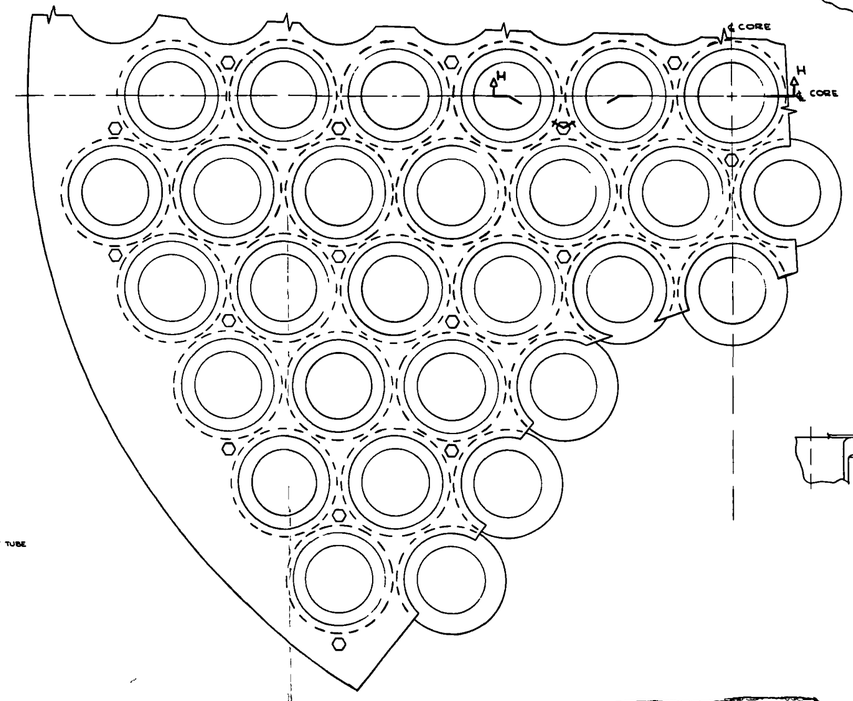


SECTION NORMAL TO FLOW AT SPRING LOCATION
SCALE 8/1

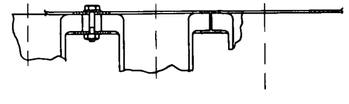


NOTE SPLINE SUPPORT SHOWN IN HOT OPERATING CONDITION. LENGTH E PROVIDES SUPPORT DURING LINER EXPANSION FROM ASSEMBLY TO OPERATING TEMPERATURE

DETAIL F
(EXIT END SUPPORT)
SCALE 8/1

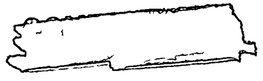


SECTION G-G
(EXIT END CONFIGURATION)
SCALE ½



SECTION H-H

Fig 6 Reference Design, TWMR Fuel Assembly



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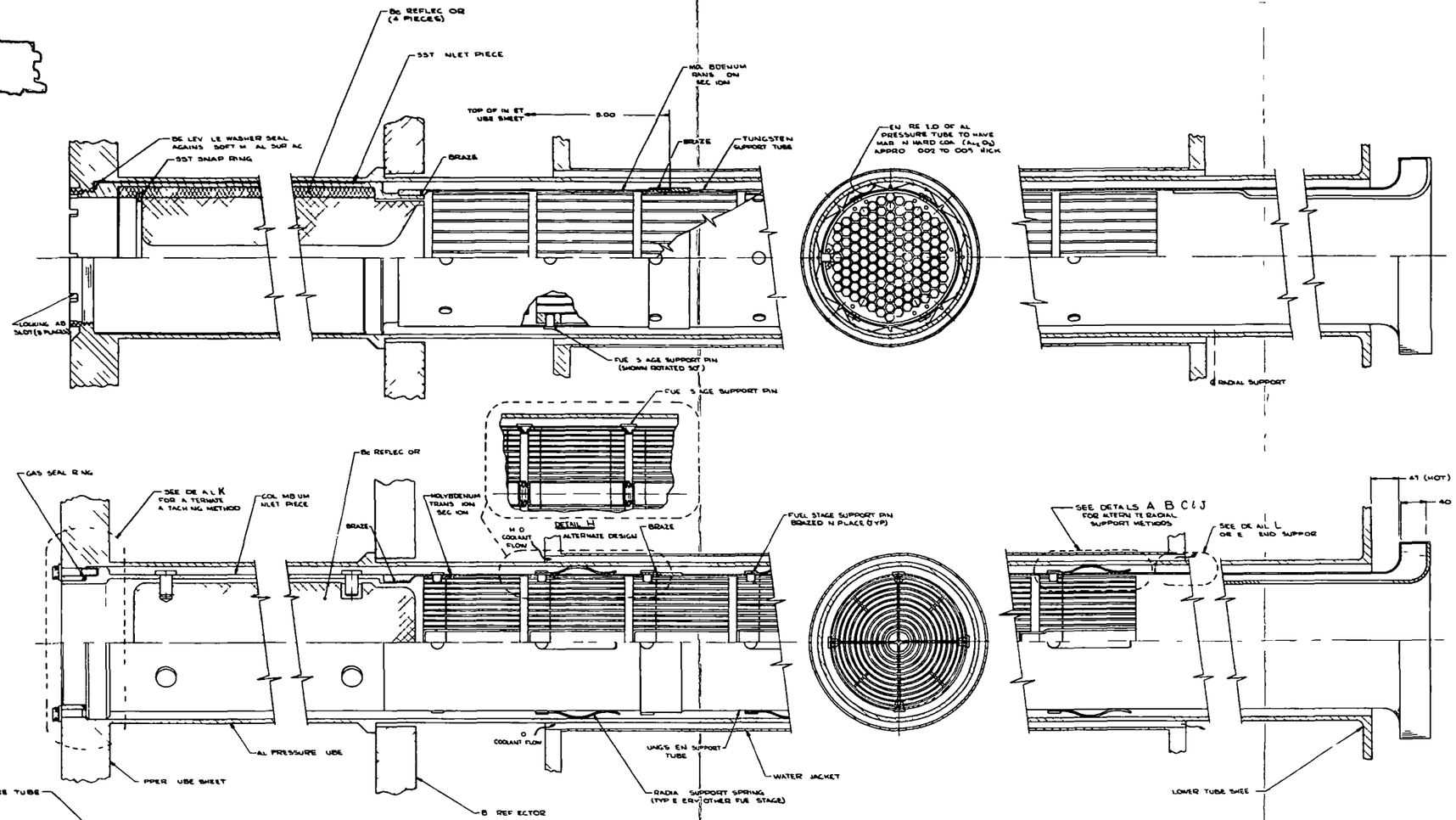


Fig 7 Alternate Concepts, TWMR Fuel Assembly

(1) Solutions for the major mechanical design areas presented in this report are obtainable without major developmental breakthroughs

(2) The lateral support spring system can be effectively analyzed and a reference design system having excellent chances of success can be predicted

(3) High temperature vibration tests of the chosen reference design lateral support system should be performed on prototype components which simulate the actual degree of fixity that would occur at various support points

The discussions of specific design areas will be separated into the major areas comprising the overall design: the inlet end configuration, support tube construction, fuel stage support, exit end configuration and the lateral support system

2 Inlet End

This portion of the fuel assembly has three basic functions attachment of the support tube to the reactor structure, sealing the gas space between support and pressure tubes, and support of the beryllium inlet reflector plug

The reference design attachment scheme uses a series of cantilever spring tabs formed by machining axial slots around the circumference of the inlet end of the fuel assembly As the fuel assembly is pushed into the core from below, the spring tabs deflect inward on passing through the inlet tube sheet, then snap out to positively lock the support tube in place A pin is shown fixed in the inlet tube sheet and engaging the locking fingers to prevent rotation of the support tube upper end This pin may be desirable or necessary if the tube is susceptible to torsional vibration even though the inlet spring tabs will exert a lateral pressure against the tube sheet, tending to dampen the vibration

The 10 inlet spring tabs shown in Fig 6 would require an axial insertion force of less than 50 pounds even if the coefficient of static friction were equal to 1

The primary advantage of the chosen design is, of course, the simplicity provided by the completely unitized attachment requiring no separate fasteners or tooling A disadvantage over a bolted joint is a reduced joint fixity during support tube bending

Alternate concepts shown on Fig 7 include a method using the spring tabs attached to the inlet tube sheet rather than as an integral part of the support tube This separation of the spring function from the support

tube allows a wider choice of materials for the spring tabs which would be stressed parts in a cryogenic environment and subjected to high neutron flux and vibration levels Other variations of the inlet attachment shown include a bolted flange arrangement and a threaded flange concept

Each method, except the bolted flange concept, requires a sealing member with a relatively low seating load (pounds per lineal inch of seal circumference) This requirement is developed from the assumption that hand assembly using no tools or fasteners by an individual standing at the exit end of the reactor is a desirable design objective Assuming that the maximum pushing force an individual should be required to exert on the fuel assembly is approximately 50 pounds, the load per lineal inch on a 2 2-inch diameter seal should be limited to 7 3 pounds Metallic seals, usually made of stainless steel, are not normally fabricated having unit sealing loads this low However, a 7075-T6 aluminum seal with either lead or gold plate on the sealing surfaces has been recommended (Ref 2) A seal of this type has been tested and required 133 pounds or 20 6 lb/lineal in for the full deflection of 0 006 inch The seal deflected 0 003 inch under 5 1 lb/lineal in Analysis of this seal in the reference design configuration indicates that a three- to six-mil assembled deflection should be adequate for operational conditions, providing the lateral vibration of the support tube does not cause significant seal unloading due to inlet end rotation

The possible variations in either seal or seal cavity design should be investigated further to obtain the least seal deflection load while still maintaining a low leakage gas seal Of course, in the case of a bolted flange design, a standard seal requiring clamping loads of approximately 60 lb/lineal in would be satisfactory

The remaining design area considered at the fuel assembly inlet end is the beryllium reflector plug The primary objective here is to provide as much beryllium volume as possible within the fuel assembly inlet This objective means providing the least necessary flow area past the inlet plug Either the peak allowable beryllium temperature or the maximum reasonable propellant flow pressure drop will limit the practically attainable beryllium volume Another consideration is attachment of the reflector plug into the fuel assembly Undoubtedly, much full-scale prototype flow testing would take place during the TWMR development During this period, it may be very advantageous to be able to change inlet plugs from the inlet end of the test assembly with no access to the fuel assembly diameters which will be surrounded by a structure mocking up the aluminum pressure tube and adjacent moderator This consideration is, of course, secondary in that interchangeability must be a design goal that may not be achieved at the cost of significantly compromising performance objectives

Thermal analysis of a solid beryllium plug with propellant flow in a 0 060-inch thick annulus around the plug showed that the maximum beryllium temperature would be about 2° F This configuration is the simplest from the beryllium fabrication standpoint and results in the longest heat flow paths within the beryllium Other coolant flow channel designs would be expected to result in lower peak beryllium temperatures Thermal stresses are well within beryllium allowable stresses It appears that a maximum allowable pressure drop in this area will limit the inlet plug design

The reference design shown in Fig 6 is the solid plug design supported by pins brazed to the support tube The forward set of pins provides axial and radial positionings while the aft set allows for axial differential expansion motions but provides radial constraint

An alternate concept, shown in Fig 7, is removable from the inlet end This uses an outer annulus comprised of four reflector segments which are held in place by an inner cylindrical reflector plug After inserting the four segments, the inner plug is inserted until it rests on a shoulder in the support tube A stainless steel snap ring is then placed in a groove in the outer reflector segments, preventing forward movement of the inner cylindrical piece Propellant flows through a central hole in the inner cylinder The central hole cooling arrangement probably will result in higher beryllium temperature than the outer annulus cooling in the reference design However, the propellant pressure drop will probably be lower due to the flow passage having an increased equivalent diameter Since the limiting criterion appears to be pressure drop rather than beryllium temperature, this alternative should be investigated further

3 Support Tube

This section covers the design and analyses of the support tube configuration and construction considered independent of the lateral support devices The support tube is a composite refractory metal tube of brazed construction to avoid the distortions inherent in welded construction Reference and alternate designs shown are based on a columbium-molybdenum-tungsten combination The composite construction is necessary because of the wide range of temperature (-138° to ≈ 4000° F) to which the support tube is exposed The tungsten and molybdenum are needed for strength at the higher temperature toward the support tube exit end However, these materials lack ductility and resistance to shock and vibration loads at lower temperatures Columbium is used from the inlet to just forward of the first fuel stage, at which point there is a brazed transition joint into a molybdenum section Thermal analysis has shown that at this location the support tube is approximately -30° F Molybdenum data (Ref 3) indicate that this temperature is

somewhat below the ductile-to-brittle transition temperature by a variable amount, depending on the material fabrication history, composition and loading conditions in service For a conservative design approach, the molybdenum transition joint shown should be located at approximately Station 12 (measured inches from forward surface of inlet tube sheet) where the predicted support tube temperature is at least 200° F

The transition to tungsten tubing is located at Station 18, where the calculated tungsten temperature is at least 1300° F, safely above the nominal transition temperature range of from 100° to 750° F given in Ref 4

Columbium is used for the inlet section since its macroscopic absorption cross section for thermal neutrons is less than one-third that of stainless steel, a perfectly acceptable structural material otherwise The thermal coefficient of expansion of columbium also matches that of molybdenum much more closely than does that of stainless steel, which could result in higher transition joint reliability

Analyses to determine the stress magnitudes in the support tube due to the axial temperature gradient impressed on the composite tube were completed for the NASA-supplied axial temperature distribution This work was done using the SEAL SHELL computer code,* of particular value for examining discontinuity stresses at transitions in tube geometry or material properties Hand calculations were also performed to examine the stresses immediately within the overlapped braze joints which were considered as concentric ring sections

Local support tube reinforcement will be necessary underneath lateral support devices The amount and location of reinforcement will vary, of course, with the final load distribution scheme chosen No problems are anticipated in providing the necessary amount of local reinforcement within the design constraint of maintaining an effective insulation between the hot support tube and the aluminum pressure tube

4 Fuel Stage Support

Several methods of fuel stage support were considered early in the contract as were two types of fuel stages Initially, both concentric ring and honeycomb cell fuel stages were studied Support methods other than pinning to the support tube were also briefly investigated, as reported in Ref 5

* See Appendix C

The reference design fuel stage support utilizes four 0 150-inch diameter pins brazed to the outer surface of the support tube and penetrating the outermost fueled ring of the concentric ring fuel stage Pins enter the fuel stage at the locations of the leading edge combs All loads from the fuel stage are carried in shear through the pins into the support tube Free axial and radial expansion of the fuel stage with respect to the support tube is allowed

Thermal analysis to examine the expected worst case temperature gradients between fueled and unfueled regions of the fuel stage was completed and is presented in a later section of this report

The pin supports used in the reference design were stress analyzed as members in pure shear The maximum axial loads on a fuel stage occur at the exit end of the fuel assembly and were calculated from the NASA-supplied flow and pressure drop data Calculated stresses for the reference design pin support arrangement appear acceptable, based on the available materials strength properties

5 Exit End

The configuration design discussed in this section is concerned with the exit insulation and the radial support structure included in this area

The exit end insulation design was considered because of its intimate relationship with the fuel assembly design at the exit end The insulation problem here is potentially more severe than is the similar problem between support tube and aluminum pressure tube because of

(1) Higher average gas temperature at the exit end than along the support tube

(2) Water flow along the pressure tube outer diameter is more capable of efficient heat removal than that along tube sheet at exit end

However, the exit end insulation scheme chosen can be shown to require a water side heat transfer coefficient of about 3100 Btu/hr-ft^2-°F for a 40° F film drop between the cooled surface of the aluminum tube sheet and the bulk water temperature

The exit end insulation design reduces heat conduction to the aluminum exit tube sheet by establishing two essentially stagnant gas volumes--one within the double-walled fuel assembly end and one between the assembly end and the tube sheet The gaps between adjacent fuel assembly ends are closed by two parallel tungsten sheets held against forward and aft surfaces of the 0 4-inch thick exit end assembly

The sheets are tied together by fasteners in the spaces between fuel assemblies Oversize holes in the sheets and ceramic coated (possibly tungsten carbide) faying surfaces allow relative movement of the sheets and assembly ends during startup and shutdown of the reactor Although the assembly would not be gastight, small weep-holes would probably have to be included to provide sufficiently rapid pressure equalization between the reactor nozzle area and the stagnant gas areas during power transients The two stagnant gas gaps provided by the exit end configuration can effectively reduce the convective heat transfer from the 4000° F core exit face to the aluminum tube sheet to acceptable levels provided that careful hydraulic design is accomplished to assure the necessary heat transfer coefficient on the water side of the aluminum tube sheet

Exit end simple support designs created to minimize the vibration response of typical lateral support systems are shown on the conceptual design drawing, Fig 6, and the alternate design concepts, Fig 7 The chosen reference design utilizes eight lugs oriented in pairs machined into a ring section which is brazed into the exit end of the support tube These lugs bear on flat surfaces machined into a stainless steel ring inserted into the aluminum pressure tube Ceramic pads at the lug interfaces increase the thermal resistance between the support and pressure tubes Flame-sprayed zirconia areas on the outer diameter of the tubular insert increase the effective heat transfer resistance from the lugs to the aluminum pressure tube Both pyrolytic graphite and zirconia were considered for the ceramic pads, and existing design data favor the use of pyrolytic graphite

Support configurations allow free axial and radial thermal expansion of the support tube within the pressure tube Lateral translation of the support tube is prevented by the lug engagement Initial clearances between mating lug surfaces are sized to produce as small an operating clearance as possible within the constraint of allowing for lug dimension changes during heating from assembly temperature to operating temperature

The support tube portion of the design would be fabricated from tungsten-25% rhenium and brazed into the basic support tube The rectangular ceramic pads at the lug interfaces will be metallized and then brazed into the metal substructure such that the ceramic is supported on four of its six flat surfaces This approach assures maximum protection against chipping or fretting wear

Pyrolytic graphite compressive strength increases with temperature and is at least 57,000 psi in the C direction at 1450° F (Ref 6) An approximately 0 0003-inch thick coating of refractory metal carbide would probably be required on the pyrolytic graphite to ensure mechanical and chemical stability

Zirconia is much weaker at temperature than pyrolytic graphite (see zirconia properties in Appendix A) but could be used without a protective coating A design compressive stress allowable for the ceramic of at least 1750 psi at about 3400° F is necessary for the reference design exit end support configuration, assuming a load of 26 lb/lug However, vibration analyses showed that this load might be about 50 lb/lug, and available data indicate that zirconia may be limited to about 250 psi at 3400° F In view of this, zirconia appears an unacceptable choice even assuming that redesign might provide a somewhat greater ceramic pad compression area An additional consideration is that the axial length of the lug must be limited to prevent wear due to rotation of the lugs during support tube vibration

Calculated stresses in the exit end lug configuration show that for approximately 50 pounds lateral force on the support lugs, stress margins of safety are acceptable For a 100-pound force, the lug bending stress becomes slightly excessive for the configuration shown

6 Lateral Support

This design area encompasses the major portion of the contract effort, and it is the one most directly dependent on the vibration analyses discussed in another section of this report Adequate control of the vibratory response of the fuel assembly and associated pressure tube is basically a problem of adjusting overall system stiffness This overall stiffness is a function of individual support and pressure tube rigidities as well as the rigidity of the devices with which the individual tube motions are coupled

Several spring designs were considered possible candidates for support tube stiffening relative to the pressure tube Two of these designs, the helical and Belleville washer types, were studied in some detail to determine the feasibility of their use in sizes compatible with the available space for mounting around the fuel assembly The Belleville springs were chosen as the reference design devices It was found that springs having individual static spring rates of several hundred pounds per inch could be designed These springs, properly arranged in groups of up to eight around the periphery of the support tube, could have an effective spring rate at a particular axial location of 1500 to 3000 lb/in In addition, experimental data generated at NASA-Lewis indicated that effective spring rates measured under dynamic conditions could be an order of magnitude higher than measured static spring rates As the vibration analyses developed, increasing the stiffness of the support tube relative to the pressure tube through the use of very high spring rate devices was found not to be sufficient It is necessary to stiffen either the pressure tube or the support tube relative to the reactor structure and is probably more effectively accomplished with the pressure tube The synthetic design approach was utilized in the vibration analysis and still more systems need to be investigated before forming more definite conclusions about the relative value of specific systems

Typical temperature distributions and design curves for helical and Belleville-type springs were developed Generalized discussions of possible spring materials are included in the analyses of the spring characteristics The plunger-type springs are considered the most reliable design approach for use in the hot end of the fuel assembly The primary reason for this is their essentially low temperature operation during the operating lifetime of the TWMR, and their ability to be assembled with an optimum preload for the system The advantages of spring preload are discussed in the analyses section Springs required to operate at or near support tube temperatures must be of a high strength refractory such as tungsten or molybdenum Such alloys are recrystallized after very few hours above 3000° F after which their strength and ductility are severely decreased

The reference design configurations are essentially based on stainless steel or superalloy springs placed in aluminum cylinders mounted in the pressure tube wall Contact with the support tube is made through zirconia buttons mounted as part of the spring assemblies Peak spring temperatures are slightly over 1300° F with these designs

C ANALYSES AND DISCUSSION

This section covers the thermal and stress analyses accomplished and its primary intent is to present a design guide and illustrate the present techniques utilized in achieving a prototype design.

1 Inlet End

a Temperature distribution, Be reflector

The temperatures in the beryllium reflector were estimated It was assumed that the reflector was a solid rod cooled by inlet hydrogen on the outer surface Thus, the problem is reduced to a simple solution of a one-dimensional rod with internal heat generation The temperature at any radius in the rod is

$$T(r) = T_s + \frac{S\left(r_1^2 - r^2\right)}{4K}$$

where

$T(r)$ = temperature at radius, r (ft)

T_s = temperature at the rod surface ($r = r_1 = 0$ 95 in)

S = internal heat generation rate (Btu/hr-ft^3)

K = thermal conductivity (85 Btu/hr-ft-°F)

The surface temperature is obtained from

$$T_s = T_g + \frac{\phi}{h} = T_g + \frac{SV}{Ah} = T_g + \frac{\pi r_1^2 L S}{2\pi r_1 L h} = T_g + \frac{S r_1}{2h}$$

where

ϕ = heat flux at the rod surface (Btu/hr-ft^2)

h = heat transfer coefficient (Btu/hr-ft^2-°F)

V = rod volume (ft^3)

A = rod surface area (ft^2)

L = rod length (ft)

T_g = gas temperature (°F)

The heat transfer coefficient is obtained from

$$h = 0\ 021 \frac{(W/A)^{0\ 8}}{D^{0\ 2}} \left(\frac{C_p^{0\ 4} K^{0\ 6}}{\mu^{0\ 4}} \right)$$

where

W = gas flow rate (3440 lb/hr)

A = flow area (ft^2)

D = hydraulic diameter (ft)

and the term in brackets is obtained from Appendix A

If a 0 060-inch annulus is assumed between the reflector and support tube,

$$A = \pi \left[(1\ 01)^2 - (0\ 95)^2 \right] / 144 = 0\ 00257 \text{ ft}^2$$

$$D = \frac{2(0\ 060)}{12} = 0\ 010 \text{ foot}$$

then h is 9380 Btu/hr-ft^2-°F

The internal heat generation rate is 22 watts/gm or (using a density of 115 lb/ft^3) 3 92 x 10^6 Btu/hr-ft^3 The maximum beryllium temperature will occur at the center (r = 0) and is

$$T(O) = -138 + \frac{3\ 92 \times 10^6 (0\ 95)}{2(12)9380} + \frac{3\ 92 \times 10^6 (0\ 95)^2}{4(85)144}$$

$$T(O) = -138 + 16\ 5 + 72\ 3$$

$$T(O) = -49\ 2^\circ F$$

The temperature rise of the hydrogen is

$$\Delta T = \frac{SV}{WC_p} = \frac{3\ 92 \times 10^6 \left[\pi(0\ 95)^2 9\right]}{1728(3440)0\ 329}$$

$$\Delta T = 51\ 1^\circ F$$

Thus, the maximum beryllium temperature is +1 9° F which is sufficiently low to preclude a design problem due to temperature levels It is expected that other coolant passage designs of equivalent hydraulic diameter would result in lower peak beryllium temperatures The thermal stresses due to the 72 3° F gradient are investigated in the following paragraphs

b Stress analysis, Be reflector

The beryllium temperature distribution is given by

$$\Delta T = \frac{S}{4K}\left(r_1^2 - r^2\right) \qquad (1)$$

where

$\Delta T = T_r - T_s$

T_r = temperature at r

T_s = surface temperature

S = internal heat generation rate

K = thermal conductivity

r_1 = outside radius = 0 95 inch

Assuming a plane strain solution, Ref 17 presents the following equations for the thermal stresses encountered in the radial, circumferential and axial directions,

$$\sigma_r = \frac{\alpha E}{1-\nu}\left[\frac{1}{r_1^2}\int_o^{r_1} T(r)\,r\,dr - \frac{1}{r^2}\int_o^{r} T(r)\,r\,dr\right] \tag{2}$$

$$\sigma_\theta = \frac{\alpha E}{1-\nu}\left[\frac{1}{r_1^2}\int_o^{r} T(r)\,r\,dr + \frac{1}{r^2}\int_o^{r} T(r)\,r\,dr - T(r)\right] \tag{3}$$

$$\sigma_z = \sigma_r + \sigma_\theta \tag{4}$$

Substituting Eq (1), the temperature distribution into Eqs (2), (3) and (4), the following is obtained.

$$\sigma_r = \frac{\alpha E}{1-\nu}\,\frac{S}{16K}\left(r^2 - r_1^2\right) \tag{5}$$

$$\sigma_\theta = \frac{\alpha E}{1-\nu}\,\frac{S}{16K}\left(3r^2 - r_1^2\right) \tag{6}$$

$$\sigma_z = \frac{\alpha E}{1-\nu}\,\frac{S}{8K}\left(2r^2 - r_1^2\right) \tag{7}$$

From Ref 18, the values for the elastic modulus and coefficient of expansion are 44×10^6 psi and 6×10^{-6} in /in -°F, respectively For $r_1 = 0\ 95$, $\nu = 0\ 3$, $S = 2\ 27 \times 10^3$ Btu/hr-in ^{3} and $K = 7\ 09$ Btu/hr-in -°F, the stresses at various radii are calculated and tabulated

r (in)	σ_r (psi)	σ_θ (psi)	σ_z (psi)
0	-6800	-6,800	-13,600
0 2	-6500	-5,900	-12,400
0 4	-5600	-3,200	-8,800
0 6	-4100	1,300	-2,800
0 8	-2000	8,000	6,000
0 95	0	13,600	13,600

The yield stress of beryllium at room temperature is far in excess of 13,600 psi

c Deflection analysis, inlet seal member

The forces causing unloading of the compressed seal member are those acting to stretch the group of latch fingers which attach the fuel assembly to the inlet tube sheet These forces are

(1) The total drag force on the fuel assembly due to propellant flow, equal to the sum of the loads on each state as presented in Fig 23

$$f_1 = 298 \text{ pounds}$$

(2) The sum of a 2 g vehicle acceleration load and a 5 g longitudinal vibration load, acting on the fuel assembly

$$f_2 = (2 + 5)33 \text{ pounds} = 231 \text{ pounds}$$

(3) The reactive force within the compressed seal member, which will vary linearly from 0 to 20 6 lb/circumferential inch as the seal is compressed 0 006 inch from its unloaded position

$$f_3 = \pi(2.2)20\ 6\left(\frac{h}{0\ 006}\right) = 23\ 8(10)^3 h \qquad (8)$$

where h is seal deflection (in)

The latch finger stretch (ignoring compression of the tube sheet under the latch fingers) under the combined loads is

$$y = \frac{Pl}{AE} \qquad (9)$$

where

$P = f_1 + f_2 + f_3$

l = latch finger unloaded length = 0 75 inch

A = latch finger total cross-sectional area, approximately 0.09 in ^{2}

E = elastic modulus, assumed $3(10)^7$ lb/in ^{2}

After fuel assembly installation and during operation, the actual seal deflection subtracted from the initial assembled seal deflection will be equal to the stretch in the latch fingers If an initial assembled seal deflection of h_1 inches is assumed, then

$$y = h_1 - h \tag{10}$$

Substituting Eqs (8) and (10) in Eq (2) and rearranging

$$h = \frac{h_1 - (529)1/AE}{23\ 8(10)^3 1/AE + 1}$$

or, for the values of l, A, E described under Eq (9)

$$h = \frac{h_1 - 1\ 47(10)^{-4}}{1\ 0066} \text{ inches,} \tag{11}$$

the actual seal deflection during operation

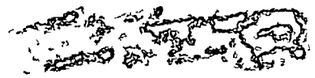
For an initial assembled deflection, h_1, of from three to six mils, the reduction in seal deflection is less than 0 2 mil due to the loads considered Further unloading of the seal due to lateral vibration of the support tube is an important consideration that was not included in this brief evaluation However, the seal design appears to be a feasible conceptual design pending further experimental and analytical investigation of the inlet end fixity during vibration

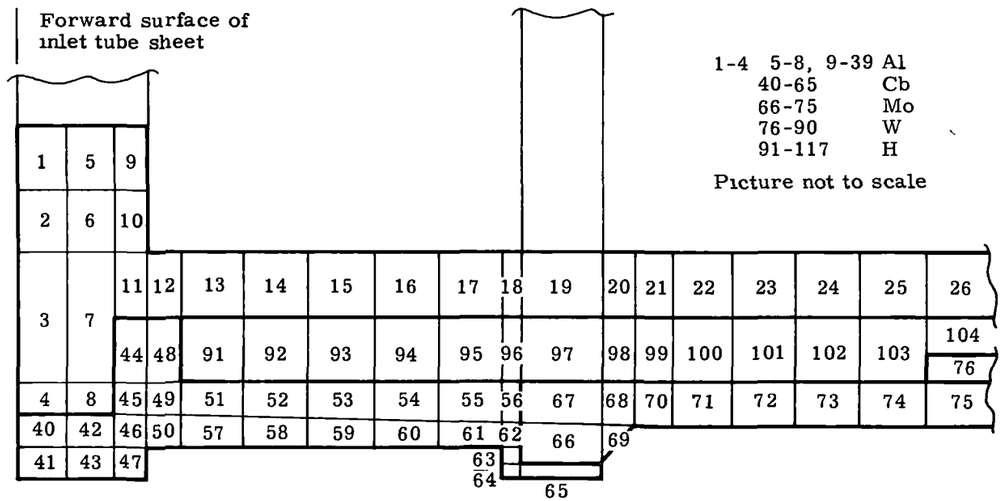
2 Support Tube

a Temperature distribution

The support tube was designed to take advantage of superior mechanical properties at the temperatures which exist along the length of the tube The inlet section is fabricated of columbium which is in contact with the cold inlet gas Brazed to the columbium is a 9-5/8-inch long molybdenum section which extends partially into the fuel region The aft section is fabricated of tungsten Figure 8 shows the model which was used for thermal analysis

Boundary conditions for the analysis consisted of forced convection of the gas to the support tube and from the aluminum pressure tube to the cooling water which was at a constant temperature of 240° F A constant heat transfer coefficient of 4000 Btu/hr-ft^2-°F was used for heat transfer to the water Radiation and conduction only were assumed between the support and pressure tubes Heat transfer coefficients (based on the correlation in Ref 7) and gas temperatures which were used along the support tube are listed in Table 1 Nodal dimensions and tube temperatures are shown in Fig 9 Material properties used are shown in Appendix A Internal heat generation rates used are shown in Figs 4 and 5





26	27	28	29	30	31	32	33	34	35	36	37	38	39
104	105	106	107	108	109	110	111	112	113	114	115	116	117
76	77												
75	78	79	80	81	82	83	84	85	86	87	88	89	90

Fig 8 Composite Liner, Thermal Model

Fig 9 Temperature Distribution in 20-Mil Support Tube

TABLE 1

Heat Transfer Coefficients and Gas Temperatures for Support Tube Analysis

Station from Inlet (in)	Heat Transfer Coefficient (Btu/hr-ft^2-°F)	Gas Temperature (°F)
0 0	2000	-138
0 3125	2000	-138
0 6250	2000	-138
1 315	2000	-138
2 005	2000	-138
3 405	2000	-138
4 805	2000	-138
6 205	2000	-138
7 605	2000	-138
9 005	2000	-138
9 065	2000	-138
9 505	2000	-138
9 723	2000	-138
9 848	2000	-138
11 848	2039	70
13 848	2060	330
15 848	2131	620
17 848	2204	910
18 163	2279	1070
18 478	2367	1130
21 478	2417	1330
24 478	2477	1700
27 478	2506	2040
30 478	2576	2340
33 478	2600	2590
36 478	2625	2820
39 478	2655	3010
42 478	2675	3180
45 478	2695	3320
48 478	2740	3420
51 478	2964	3510
54 478	3070	3992

b Support tube stresses

In the reference design of the support tube, three lap jointed and brazed sections incorporating three refractory materials are selected to avoid structural problems associated with the nil ductility transition temperatures If the support tube was manufactured of one material,

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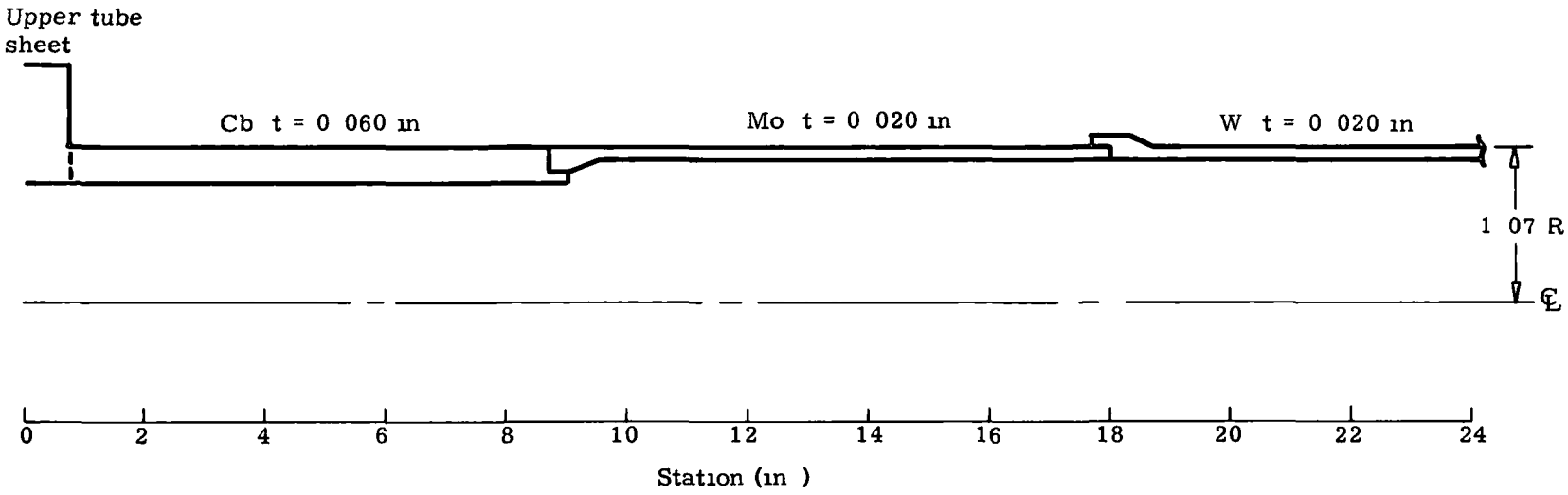

Fig 10 Structural Model for the Determination of Thermal and Pressure Discontinuity Stresses

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discontinuity stresses would occur only at the interface between the upper end of the liner and the inlet tube sheet With three materials, however, and their associated operational temperature and pressure distributions, discontinuity stresses will result from differences in circumferential strain at the brazed joints. These discontinuity stresses will occur in the shell sections adjacent to the lapped joints The stresses developed within the joints are based upon an interference fit of the two shells at temperature Thermally induced strains occur in the lap joints at temperature other than the brazing temperature of about 1850° F

The determination of discontinuity stresses resulting from the requirement of slope and deflection compatibility is relatively simple in theory and is treated in varying degrees of detail in many texts However, a design having four or five regions of discontinuity involving both mechanical and thermal strains suggests a relatively high degree of arithmetic complexity In this case, SEAL SHELL 2, a computer program developed to provide the analytic solution for axisymmetric shells and plates, was applied Briefly, the technique requires subdivision of the support tube into a finite number of segments with applicable pressure loading and material properties written as a function of the temperature The solution is obtained from compatibility equations, equations of elasticity and strain-energy relationships Appendix C provides a detailed operating manual and description of the SEAL SHELL program

During the conceptual design phase, a columbium-molybdenum-tungsten support tube with the following dimensions was studied in detail

Material	Length (approximate) (in)	Wall Thickness (in)	Outer Diameter (in)
Columbium	9	0 060	2 14
Molybdenum	9	0 020	2 14
Tungsten	37	0 020	2 14

A sketch of this configuration is shown in Fig 10 Note that the shell midplanes of the columbium and molybdenum sections are not concurrent at the junctions and thus suggest additional allowances to be made in an analytical treatment of the discontinuities This eccentricity of the middle surfaces induces bending stresses in addition to those normally found for shell junctions which have continuous middle surfaces In addition, local tapers are associated with the lap joints to reduce local stress magnitudes Thus, the justification in applying a computer program to these geometric complexities was obvious

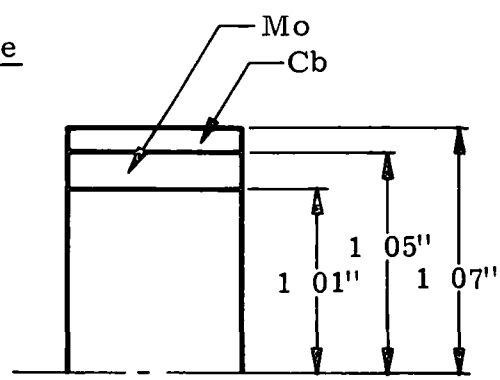
Figure 11 provides the longitudinal distribution of support tube temperature and applied pressure Figure 12 illustrates the modulus of elasticity and coefficient of thermal expansion as a function of axial station

An accurate solution of the problem by means of the computer program requires that the model be subdivided into many elements Of course, prime importance is placed upon the subdivisions beyond an attenuation length from each joint interface The computer model, its associated element geometry and characteristics are shown in Fig 13 The tabulated data provided the major percentage of data input Figures 14, 15, 16 and 17 present the circumferential and meridional stresses associated with temperature and pressure which may be superimposed They are not added in the figures since the thermal and mechanical stresses fall within two separate categories with respect to the allowable stress criteria

The circumferential discontinuity stresses and stress distributions apply to the singular tube sections as previously stated Negligible influence by these stresses in the lapped sections is assumed since the lapped sections act as rings and have relatively high rigidity The principal stresses in the bimetallic lap joints are based upon the interference fits associated with ambient and operational temperatures It is assumed that the tube dimensions correspond (no interference) at the brazing temperature of 1850° F The section geometries, temperature ranges and mechanical properties are shown Case 1 represents stresses generated from the temperature differential between brazing and ambient temperatures Case 2 represents the change from brazing to operational temperature

Case 1--Braze to Ambient Temperature

Mo-Cb interface

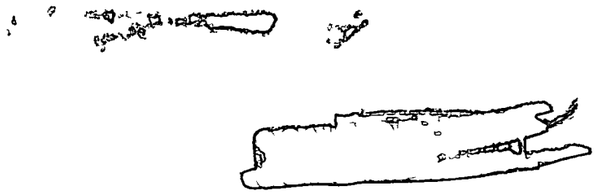


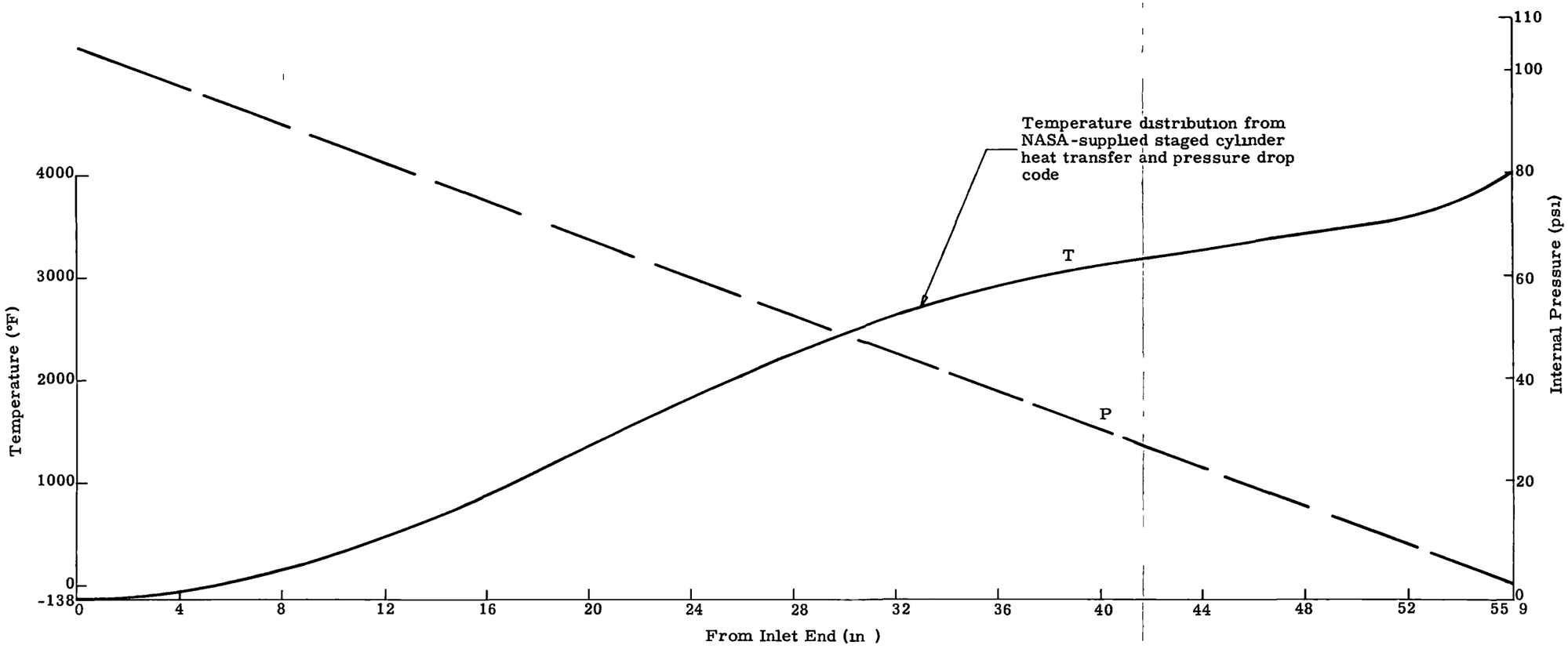
T = 70° F

E_{Cb} = 24 8 x 10^6 psi

T = 1850° F

E_{Cb} = 19 65 x 10^6 psi





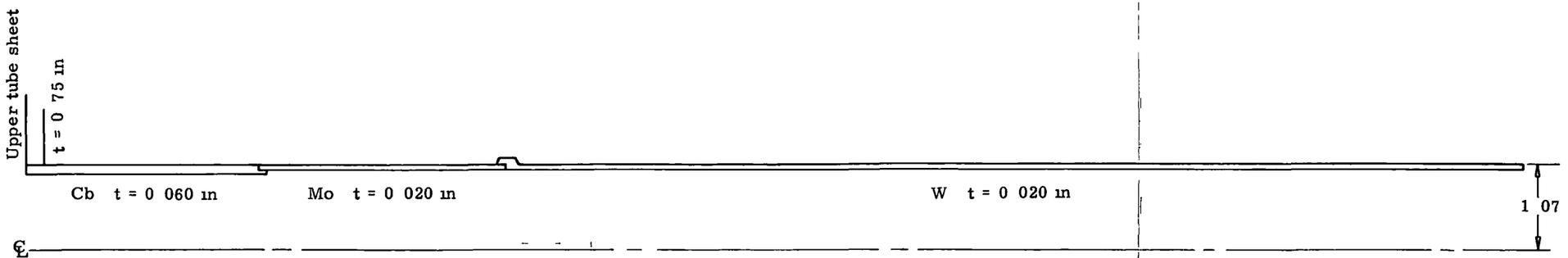


Fig 11 Temperature and Pressure as a Function of Axial Station, Cb-Mo-W Support Tube

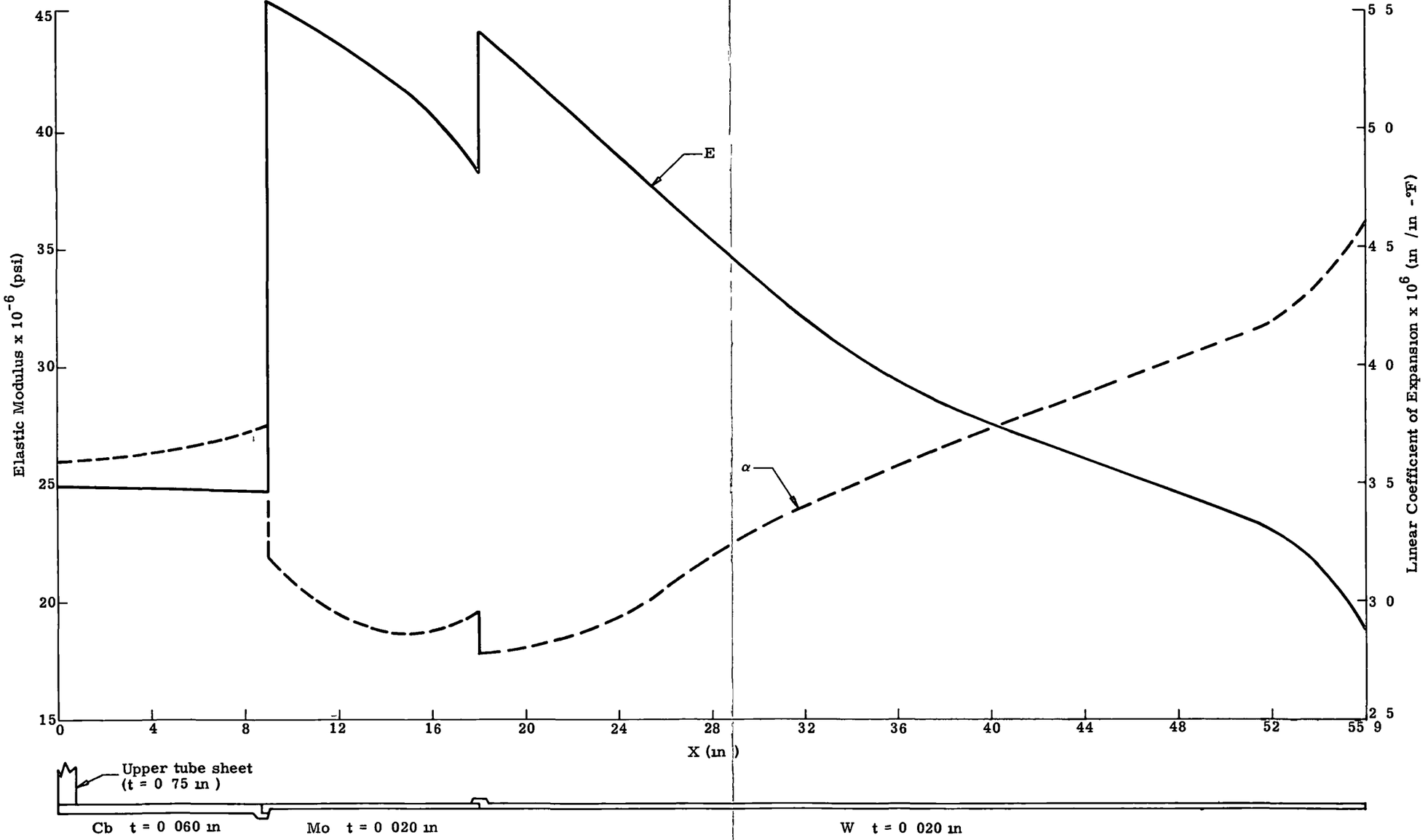
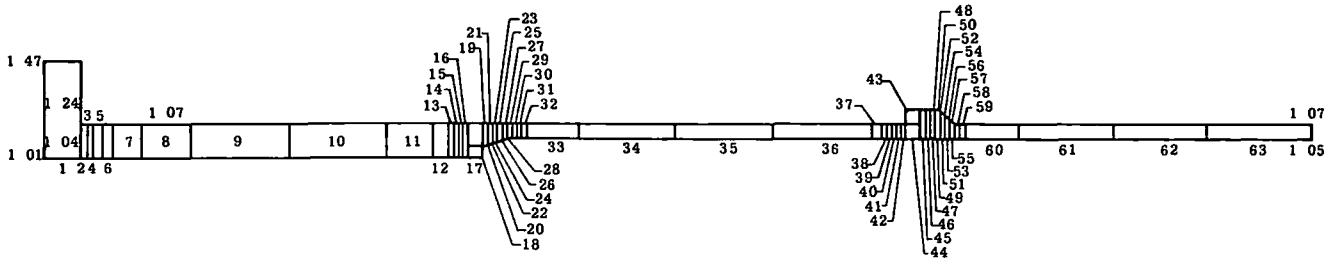

Elastic Modulus x 10^{-6} (psi)
Linear Coefficient of Expansion x 10^{6} (in /in -°F)
E
α
X (in)
Upper tube sheet
(t = 0 75 in)
Cb t = 0 060 in
Mo t = 0 020 in
W t = 0 020 in

Fig 12 Elastic Modulus and Coefficient of Thermal Expansion as a Function of Axial Station, Cb-Mo-W Support Tube



X (in)	Element No	R (in)	Z (in 3)	t (in)	T (°F)	E x 10 6 (psi)	G x 10 6 (psi)	α x 10 6 (in /in °F)	P1 (psi)
0	0	1 24	26						
0 75	1	1 24	25 25	0 46	138	10	3 8	12	105
0 75	2	1 14	25 25	0 20	138	24 9	9 6	3 6	104
0 9	3	1 04	25 1	0 06	134	24 86		3 6	104
1	4		25		130	24 83		3 6	103
1 2	5		24 8		125	24 84		3 65	102 5
1 4	6		24 6		120	24 83	9 6	3 65	102
2	7		24		110	24 82	9 5	3 7	101
3	8		23		100	24 8			99 3
5	9	1 04	21		0	24 75			96
7	10		19		70	24 73			92
8	11		18		140	24 72			90
8 3	12		17 7		160	24 71			89 3
8 4	13		17 6		170	24 71			89 2
8 5	14		17 5		175	24 71			89
8 6	15		17 4		185	24 71		3 7	88 7
8 7	16		17 3		200	24 7	9 5	3 74	88 2
9	17	1 04	17	0 06	210	38 6	14 8	3 4	88
9	18	1 046	17	0 012	210	45 6	17 5	3 2	88
9 1	19	1 052	16 9	0 036	220	45 4		3 1	87 8
9 1	20	1 053	16 9	0 002	220				
9 2	21	1 054	16 8	0 032	230				
9 2	22	1 055	16 8	0 002	230				
9 3	23	1 056	16 7	0 028	240				
9 3	24	1 057	16 7	0 002	240	45 4	17 5		87 8
9 4	25	1 058	16 6	0 024	250	45 3	17 4		87 5
9 4	26	1 0585	16 6	0 001	250	45 3			87
9 5	27	1 059	16 5	0 022	240				
9 5	28	1 0595	16 5	0 001	240				
9 6	29	1 06	16 4	0 02	270				
9 7	30		16 3		280				
9 8	31		16 2		285	45 3	17 4	3 1	87
9 9	32		16 1		290	45	17 3	3 08	86
11	33		15		370	44 4	17 1	3 01	84 5
13	34		13		550	43	16 5	2 93	81
15	35		11		750	41 5	16 0	2 86	77
17	36		9		980	40	15 4	2 83	73
17 2	37		8 8		1000				72
17 3	38		8 7		1015				
17 4	39		8 6		1030				
17 5	40		8 5		1040				
17 6	41		8 4		1055	40	15 4	2 83	
17 7	42	1 06	8 3	0 02	1070	38 2	14 7	2 8	
17 7	43	1 065	8 3	0 01	1070	38 2	14 7	2 78	72
18	44	1 07	8	0 04	1100	41 2	15 8	2 86	71 5
18 1	45	1 07	7 9	0 04	1115	44 2	17 0	2 85	70 5
18 2	46	1 07	7 8	0 04	1130	43 8	16 8	2 9	
18 3	47	1 07	7 7	0 04	1140				
18 3	48	1 069	7 7	0 002	1140				
18 4	49	1 068	7 6	0 036	1155				
18 4	50	1 067	7 6	0 002	1155				
18 5	51	1 066	7 5	0 032	1170				
18 5	52	1 065	7 5	0 002	1170				
18 6	53	1 064	7 4	0 028	1185				
18 6	54	1 063	7 4	0 002	1185				
18 7	55	1 062	7 3	0 024	1200				
18 7	56	1 061	7 3	0 002	1200				
18 8	57	1 06	7 2	0 02	1210				
18 9	58		7 1		1220	43 8	16 8	2 9	70 5
19	59		7		1230	43 4	16 7	2 79	69 5
20	60		6		1360	42	16 2	2 82	67
22	61		4		1600	40 7	15 7	2 86	64
24	62	1 06	2		1820	38 9	15 0	2 96	60
26	63	1 06	0	0 02	2050	37 2	14 3	3 06	56

Fig 13 SEAL SHELL Model, Cb-Mo-W Support Tube

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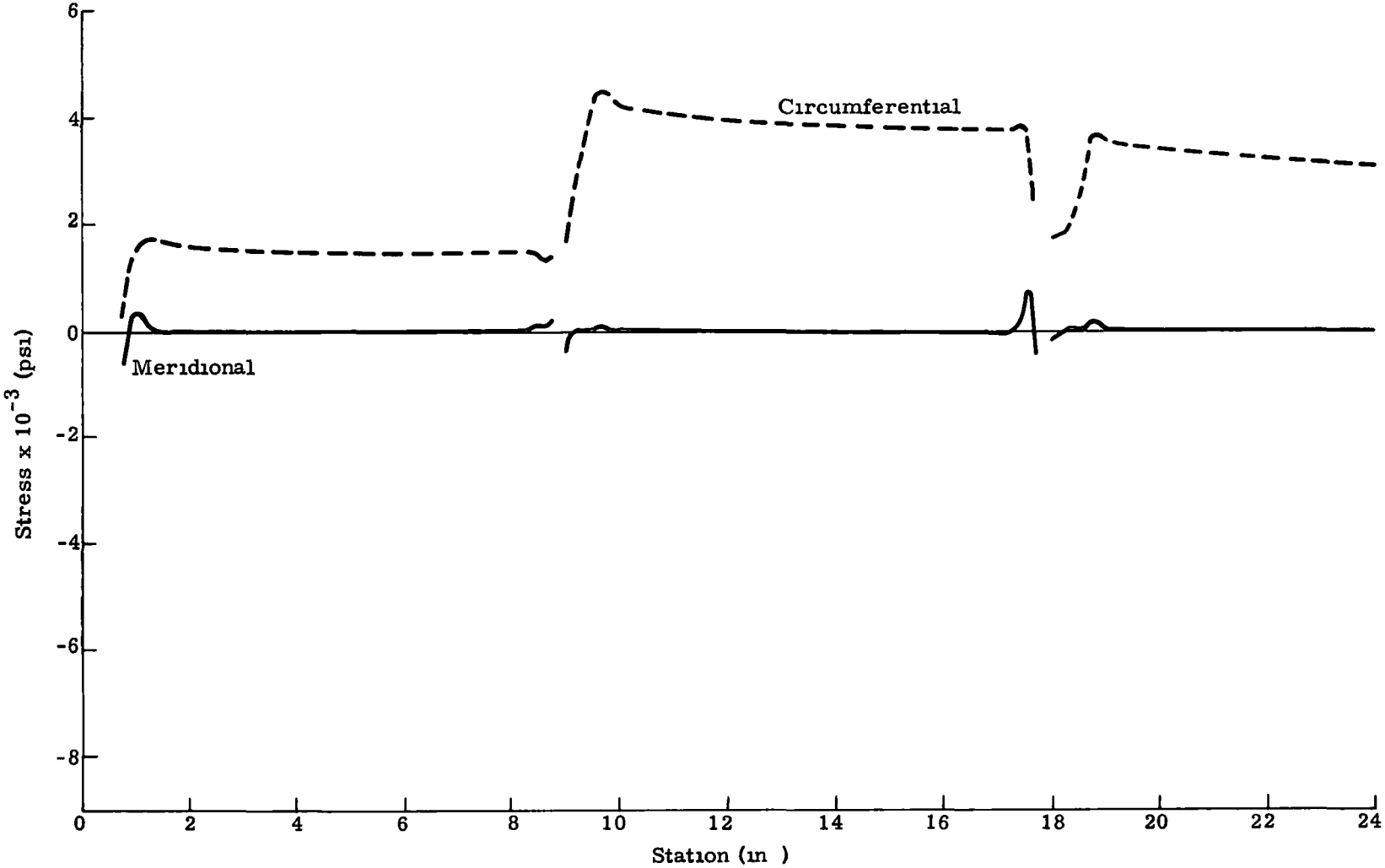

Fig 14 Pressure Discontinuity Stresses, Outer Surface

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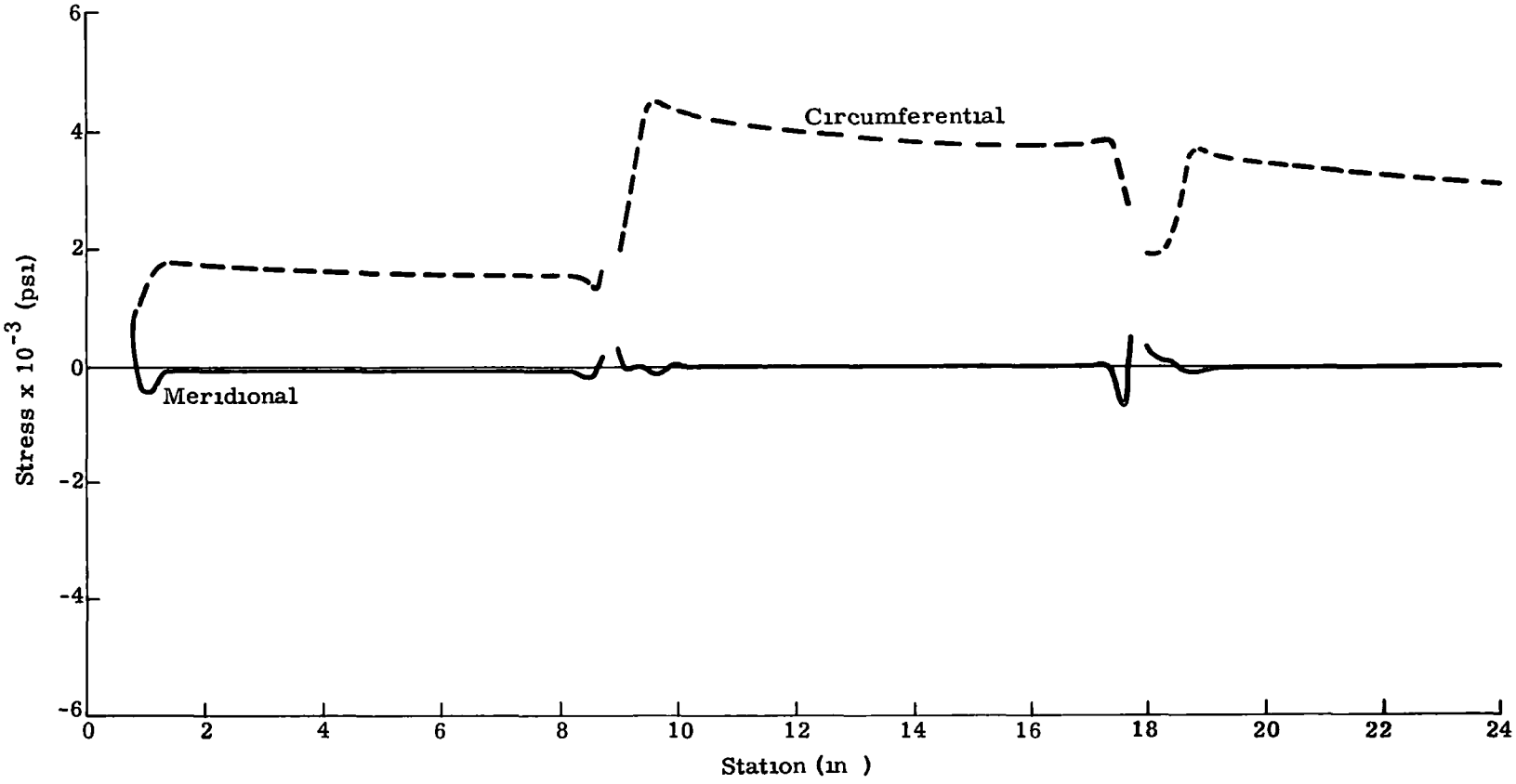

Fig 15 Pressure Discontinuity Stresses, Inner Surface

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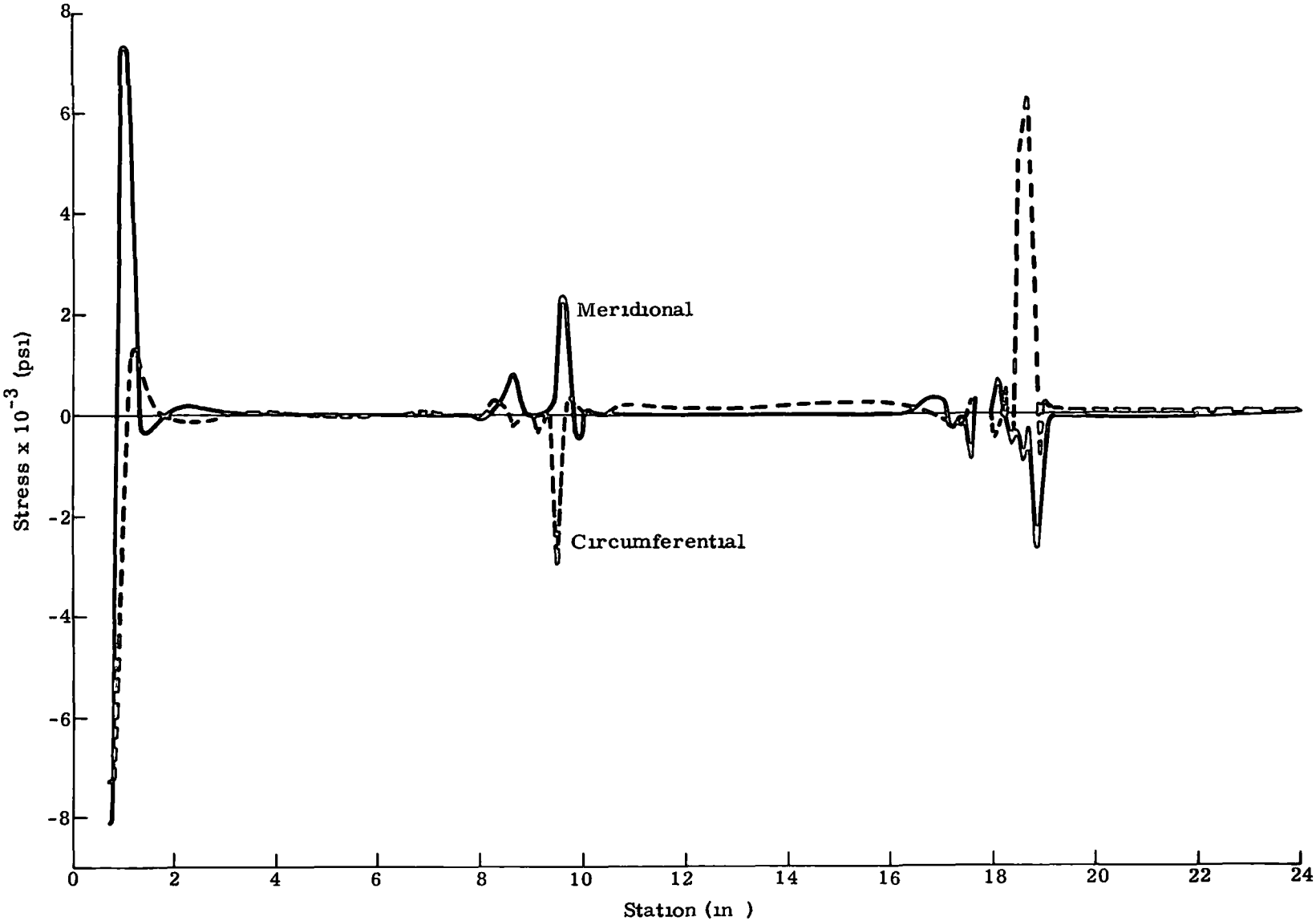

Fig 16 Thermal Discontinuity Stresses, Outer Surface

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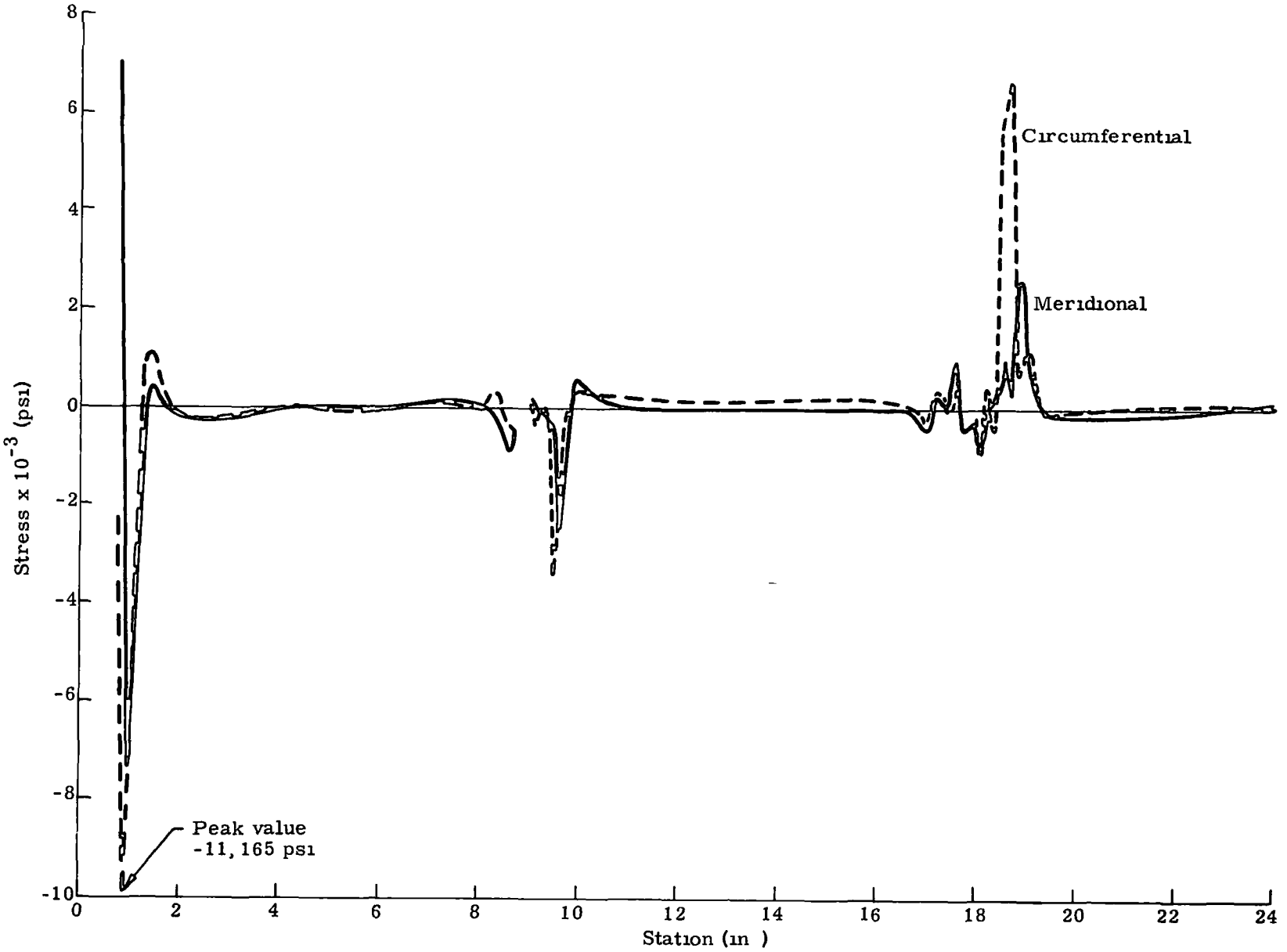

Fig 17 Thermal Discontinuity Stresses, Inner Surface

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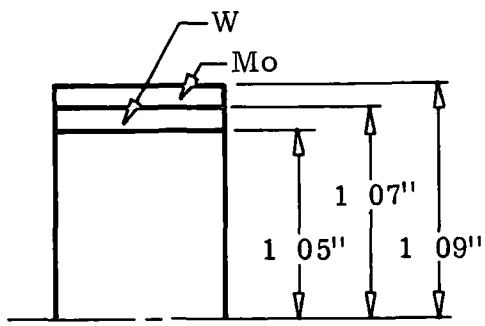
E_{Mo} = 46 4 x 10^6 psi	E_{Mo} = 30 2 x 10^6 psi
α_{Cb} = 3 7 x 10^{-6} in /in °F	α_{Cb} = 4 44 x 10^{-6} in /in °F
α_{Mo} = 3 25 x 10^{-6} in /in °F	α_{Mo} = 3 25 x 10^{-6} in /in °F
P_1 (internal pressure) = 0	P_1 = 0

Mo-W interface



T = 70° F	T = 1850° F
E_{Mo} = 46 4 x 10^6	E_{Mo} = 30 2 x 10^6
E_W = 49 7 x 10^6	E_W = 38 8 x 10^6
α_{Mo} = 3 25 x 10^{-6}	α_{Mo} = 3 25 x 10^{-6}
α_W = 2 5 x 10^{-6}	α_W = 2 95 x 10^{-6}
P_1 = 0	P_1 = 0

Case 2--Braze to Operational Temperature

Mo-Cb interface

T = 1850° F	T = 400° F
E_{Cb} = 19 65 x 10^6 psi	E_{Cb} = 25 x 10^6 psi
E_{Mo} = 30 2 x 10^6 psi	E_{Mo} = 44 x 10^6 psi
α_{Cb} = 4 44 x 10^{-6} in /in °F	α_{Cb} = 3 8 x 10^{-6} in /in °F
α_{Mo} = 3 25 x 10^{-6} in /in °F	α_{Mo} = 3 x 10^{-6} in /in °F
P_1 = 0	P_1 = 85 psi

Mo-W interface

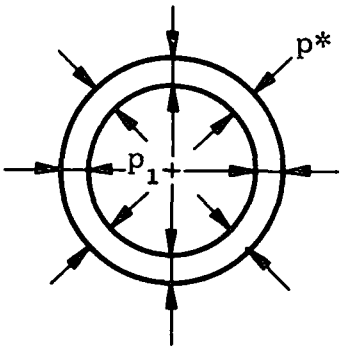
$T = 1850°\ F$	$T = 1200°\ F$
$E_{Mo} = 30\ 2 \times 10^6$	$E_{Mo} = 37 \times 10^6$
$E_W = 38\ 8 \times 10^6$	$E_W = 43 \times 10^6$
$\alpha_{Mo} = 3\ 25 \times 10^{-6}$	$\alpha_{Mo} = 3 \times 10^{-6}$
$\alpha_W = 2\ 95 \times 10^{-6}$	$\alpha_W = 2\ 8 \times 10^{-6}$
$P_1 = 0$	$P_1 = 70$ psi

From Ref 16, p 210, the radial displacement of a thick-walled cylindrical shell is given by

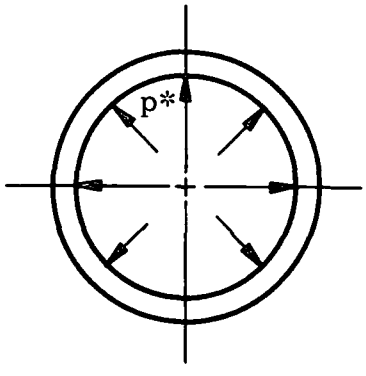
$$U = \frac{1 - \nu}{E}\left(\frac{a^2 p_1 - b^2 p_o}{b^2 - a^2}\right) r + \frac{1 + \nu}{E}\left[\frac{a^2 b^2 (p_1 - p_o)}{(b^2 - a^2)\, r}\right] \qquad (12)$$

where a = inside radius and b = outside radius The problem encountered here is the case of two heated cylinders at each joint whereby the linear expansion coefficient is larger for the outer cylinder in each instance Temperature changes affect the interference pressure at the interface In addition, an internal pressure exists for the operational case

Consider two cylindrical shells, as shown, with the following radii and loading p* represents the interference pressure



Inside radius = a
Outside radius = b
$E = E_1$



Inside radius = c = b
Outside radius = d
$E = E_2$

To obtain the interference pressure, p*, reference is made to Ref 16, p 211, where the radial deformation across the interface is given by

$$\delta = \frac{cp^*}{E_2}\left(\frac{c^2 + d^2}{d^2 - c^2} + \nu\right) + \frac{bp^*}{E_1}\left(\frac{a^2 + b^2}{b^2 - a^2} - \nu\right) \tag{13}$$

With c = b and solving for p*,

$$p^* = \frac{\delta}{b}\left\{\frac{1}{\frac{1}{E_2}\left[\frac{c^2 + d^2}{d^2 - c^2} + \nu\right] + \frac{1}{E_1}\left[\frac{a^2 + b^2}{b^2 - a^2} - \nu\right]}\right\} \tag{14}$$

The radial deformation, δ, is equal to the radial deformation, U_b, of the inside cylinder at the interface due to p_1 plus the radial contraction, Δ_c, of the outer cylinder less the radial deformation, Δ_b, of the inner cylinder due to radial contraction Therefore,

$$\delta = U_b - \Delta_b + \Delta_c \tag{15}$$

From Eq (12), U_b may be obtained by applying p_1 to the internal cylinder where r = b Thus,

$$U_b = \frac{1 - \nu}{E_1}\left(\frac{a^2 p_1}{b^2 - a^2}\right)b + \frac{1 + \nu}{E_1}\left[\frac{a^2 b^2 p_1}{(b^2 - a^2)b}\right]$$

$$U_b = \frac{2p_1 a^2 b}{E_1(b^2 - a^2)} \tag{16}$$

Referring to the brazed joint cases previously illustrated and applying Eqs (15) and (16)

For Case 1a

$\Delta_b = 6\ 074 \times 10^{-3}$ inch

$\Delta_c = 7\ 607 \times 10^{-3}$ inch

$\longrightarrow \delta = 0\ 001533$ inch

For Case 1b

$$\Delta_b = 5\ 19 \times 10^{-3} \text{ inch}$$

$$\Delta_c = 6\ 19 \times 10^{-3} \text{ inch}$$

$$\longrightarrow \delta = 0\ 001 \text{ inch}$$

For Case 2a

$$\Delta_b = 4\ 758 \times 10^{-3} \text{ inch}$$

$$\Delta_c = 6\ 273 \times 10^{-3} \text{ inch}$$

$$U_b = 5\ 022 \times 10^{-5} \text{ inch}$$

$$\longrightarrow \delta = 0\ 001565 \text{ inch}$$

For Case 2b

$$\Delta_b = 2\ 00 \times 10^{-3} \text{ inch}$$

$$\Delta_c = 2.173 \times 10^{-3} \text{ inch}$$

$$U_b = 9\ 058 \times 10^{-5} \text{ inch}$$

$$\longrightarrow \delta = 0\ 000264 \text{ inch}$$

The interference pressures are calculated directly from Eq (14) with the following results

Case	p*
1a	540
1b	420
2a	550
2b	92

From Ref 16, p 208, the circumferential stress distribution for a thick-walled cylinder is given by

$$\sigma_\theta = \frac{a^2 p_1 - b^2 p_o}{b^2 - a^2} + \frac{(p_1 - p_o) a^2 b^2}{r^2 (b^2 - a^2)} \qquad (17)$$

Utilizing this basic equation, the stress distribution through the laminated or brazed sections is provided in Table 2 The yield capability of the materials at the temperatures of interest is also included

TABLE 2

Stress Distribution

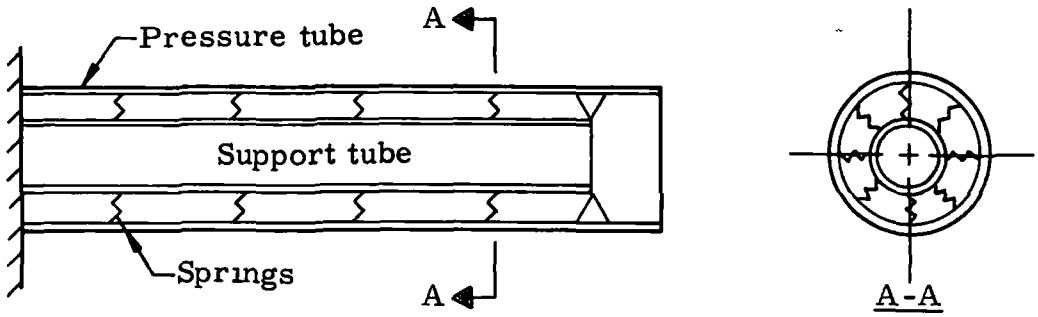
Case	Material	Temperature (°F)	r (in)	Calculated (psi)	σ_y * (psi)
1a	Mo	70	1 01	-14,450	83,000
1a	Mo	70	1 03	-14,172	83,000
1a	Mo	70	1 05	-13,910	83,000
1a	Cb	70	1 05	29,351	105,000
1a	Cb	70	1 06	29,207	105,000
1a	Cb	70	1 07	29,065	105,000
1b	W (rc)	70	1 05	-22,682	>50,000
1b	W (rc)	70	1 06	-22,469	>50,000
1b	W (rc)	70	1 07	-22,262	>50,000
1b	Mo	70	1 07	23,491	83,000
1b	Mo	70	1 08	23,376	83,000
1b	Mo	70	1 09	23,264	83,000
2a	Mo	400	1 01	-12,529	67,000
2a	Mo	400	1 03	-12,289	67,000
2a	Mo	400	1 05	-12,064	67,000
2a	Cb	400	1 05	29,895	98,000
2a	Cb	400	1 06	29,748	98,000
2a	Cb	400	1 07	29,603	98,000
2b	W (rc)	1200	1 05	-1,258	17,500
2b	W (rc)	1200	1 06	-1,247	17,500
2b	W (rc)	1200	1 07	-1,236	17,500
2b	Mo	1200	1 07	5,145	48,000
2b	Mo	1200	1 08	5,120	48,000
2b	Mo	1200	1 09	5,101	48,000

*See Appendix A

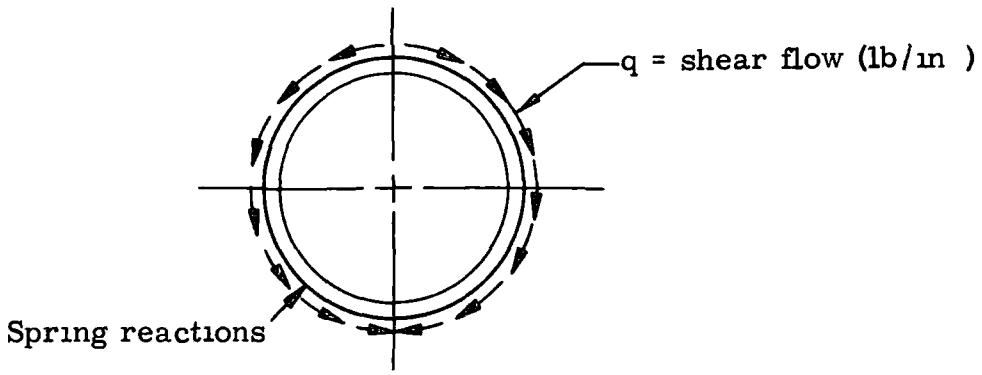
d Local support tube stresses due to support spring loading

Axial support is provided at several locations by compression springs which are symmetrically placed around the support tube circumference These springs are radially located by the aluminum pressure tube and apply force on the support tube outside diameter A sketch of a typical system is shown

At each axial spring location the support tube must be reinforced to reduce local stresses This reinforcement is gained by thickening the tube over a limited axial length around the entire circumference



For purposes of analysis, the local reinforcement is assumed to act as a continuous ring Also, stiffening by the adjacent tube material is conservatively neglected The lateral load imposed at each axial spring location is assumed to act as a shear flow through the reinforcement ring and to be reacted radially by the circumferentially placed springs A sketch of this load distribution is shown

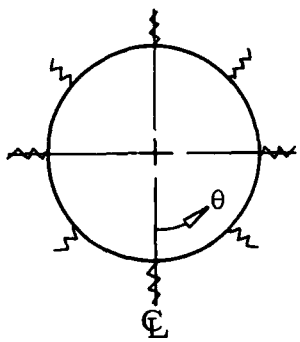


A general approach is used to determine the maximum ring stress so that any of several symmetrical arrays of support springs may be evaluated Specifically, arrays of 6, 8, 12 and 16 circumferential springs are considered In Table 3 the individual spring reactions, based on a 100-pound lateral load, are given for each array

From previous work, it has been found that in most instances the ring maximum stress occurs at the point of maximum moment Hence, a general approach for finding the location and magnitude of maximum moment will be developed and procedures for calculating the corresponding stress given Briefly, a plot of ring bending moment (M) versus radial location (X) for a single spring array and a 100-pound load is drawn in Fig 18 Knowing individual spring loads and locations (Table 3) for a symmetrical arrangement of springs, the ring moment distribution can be found for each spring load by use of Fig 18 From the principle of superposition, the maximum ring moment may now be determined For total stress the ring hoop force at the point of maximum moment is also required A plot of hoop force versus radial location (X) for a single spring array and a 100-pound unit load is shown in Fig 19 Knowing the maximum moment and corresponding hoop force, the maximum stress is now determined

TABLE 3

Spring Loads for Several Symmetrical Spring Arrangements



η = number of springs
θ = spring location (degrees)

	Spring Load (lb)					
	θ / 0°	22 5°	30°	45°	60°	67 5°
6	66 7	--	--	--	33 33	--
8	50	--	--	35 35	--	--
12	33 33	--	28 8	--	16 7	--
16	25	22 9	--	17 7	--	9 6

NOTE

In all cases, two springs are located along the support tube centerline

To illustrate how the maximum ring stress is determined for any vertical load and symmetrical spring array, an example problem is shown

The assumptions used were

(1) Total vertical load of 100 pounds

(2) Eight circumferential springs (η = 8)

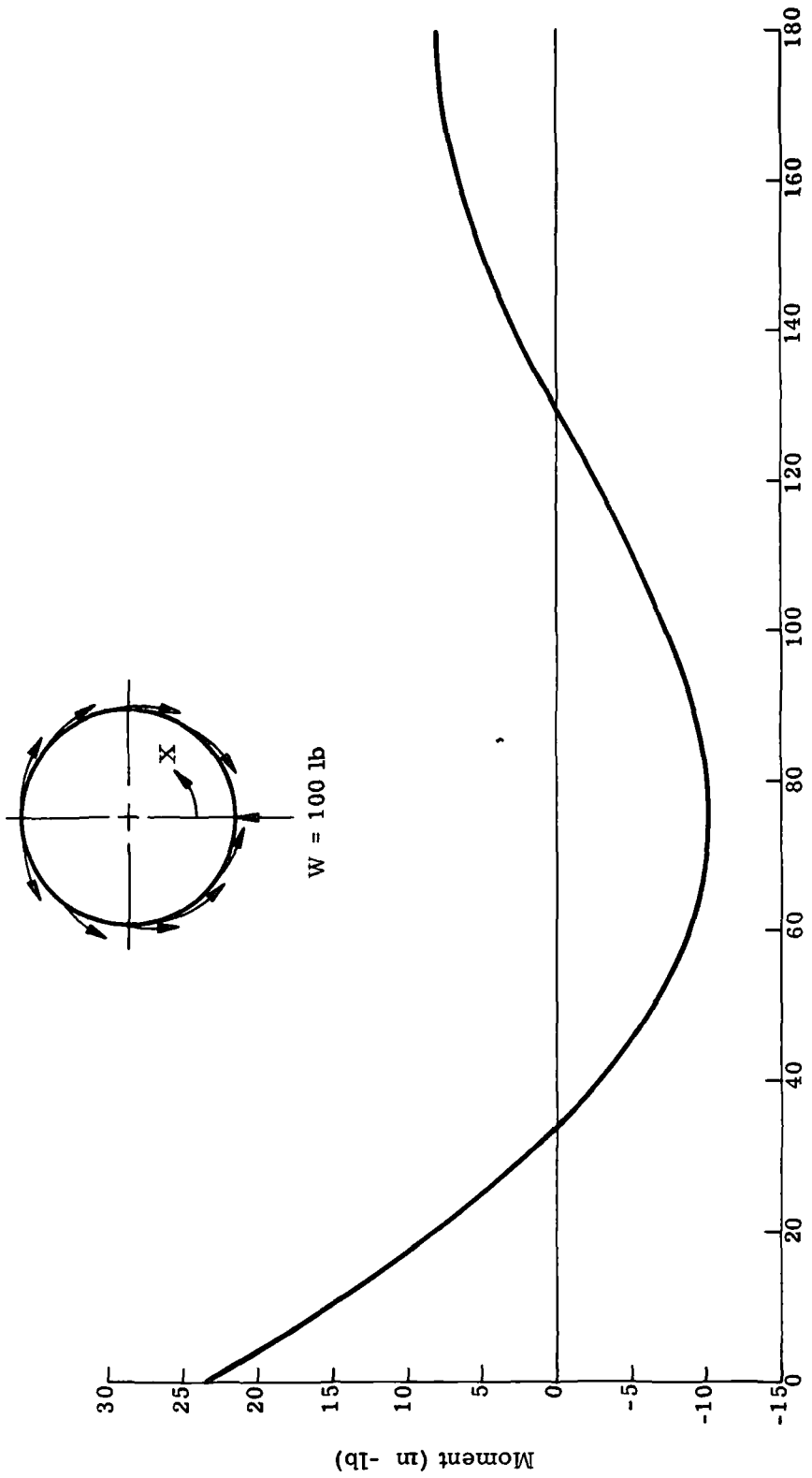


Fig 18 Ring Moment Distribution for a 100-Pound Lateral Load

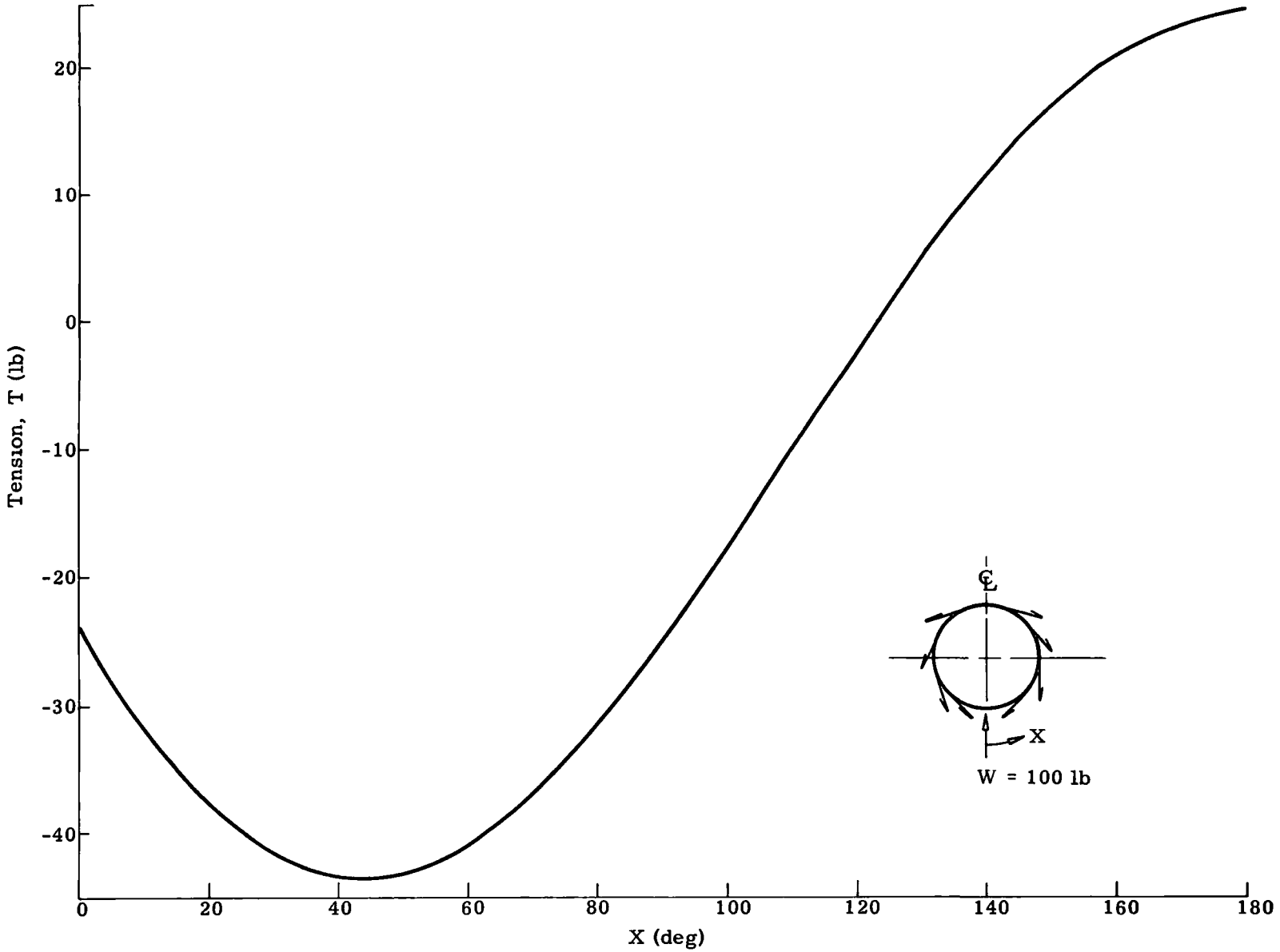


Fig 19 Ring Circumferential Tension Distribution for a 100-Pound Lateral Load

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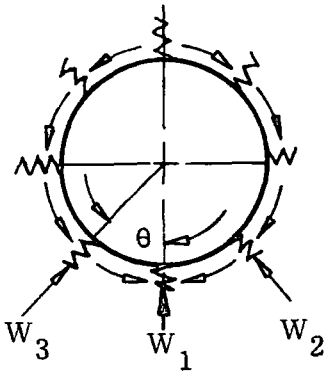
Step 1 From Table 3 find active spring reactions



P = 100 pounds

θ = 45 degrees

W_1 = 50 pounds

$W_2 = W_3$ = 35 35 pounds

Step 2 Using the moment distribution curve, shown as Fig 18, determine ring moment distribution for loads W_1, W_2 and W_3

Step 3 Plot curves of moment distributions From individual moment curves, draw the combined moment curve by applying the principle of superposition For this example the moment curves are shown as Fig 20

Step 4 From Fig 20, determine the magnitude and location of the maximum moment

X = 0 degree

M = maximum moment = 8 4 in -lb

Step 5 At the point of maximum moment, find and combine the magnitude of circumferential tension by using Fig 19

X = 0 degree

T_1 = circumferential ring load = $-23\ 8\left(\frac{50}{100}\right)$ = -11 9 pounds due to W_1

T_2 = ring load = $-43\ 5\left(\frac{35\ 35}{100}\right)$ = -15 4 pounds due to W_2

T_3 = ring load = $-43\ 5\left(\frac{35\ 35}{100}\right)$ = -15 4 pounds due to W_3

$T_{tot} = \Sigma T$ = -42 7 pounds

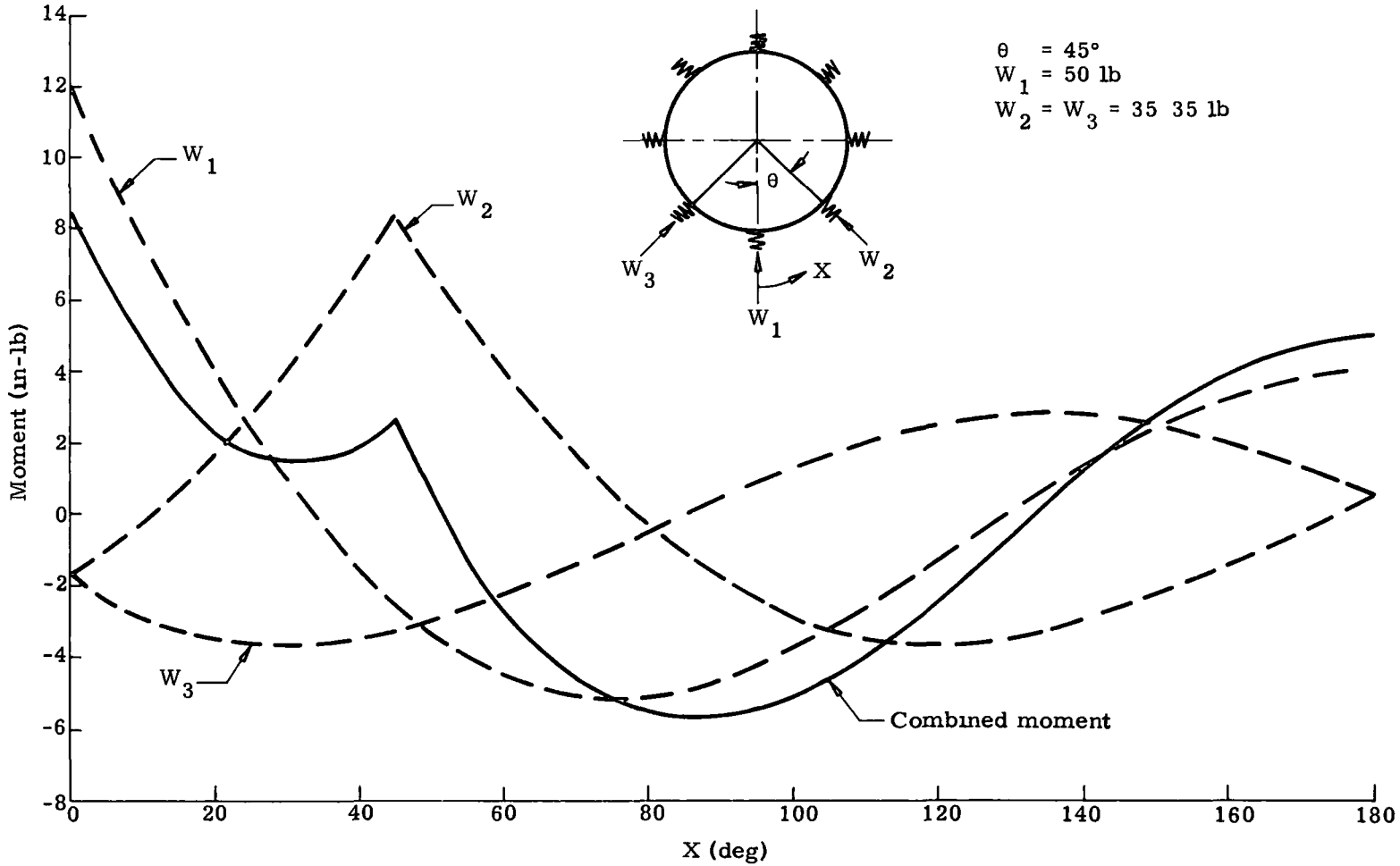


Fig 20 Moment Distribution for a 100-Pound Lateral Load and Eight Springs

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Step 6 Determine the maximum combined stress

Bending stress (σ_b)

$$\sigma_b = \frac{6M}{bt^2} = \frac{6(8\ 4)}{bt^2} = \pm \frac{50\ 4}{bt^2}$$

where

b = ring length (in)

t = ring thickness (in)

Circumferential stress (σ_c)

$$\sigma_c = \frac{T_{tot}}{bt} = \frac{-4\ 27}{bt}$$

hence, the maximum ring stress is

$$\sigma_{max} = \sigma_b + \sigma_c = -\frac{50\ 4}{bt^2} - \frac{42\ 7}{bt}$$

A plot of stress versus ring thickness is shown as Fig 21 This plot is based on a unit moment (M) of 10 in -lb, a unit circumferential force (T) of 100 pounds and a unit ring span (b) of one inch For the example problem, assuming a ring thickness of 0 100 inch, the following stress is calculated

$$\sigma_{tot} = 6000\,\frac{8\ 4}{10} + 1000\,\frac{42\ 7}{100} = 5467 \text{ psi}$$

In the example, no spring preload was assumed Preload can readily be accounted for by additional superposition of moments and hoop forces once the magnitude of preload is established

3 Fuel Stage

a Radial temperature distribution at first stage inlet

The temperature distributions in the inlet support combs and fuel rings were determined for the first stage Since the first stage sees the coldest inlet gas temperature, it was reasoned that the first stage would be subjected to the greatest temperature gradients and, thus, the most severe thermal stress

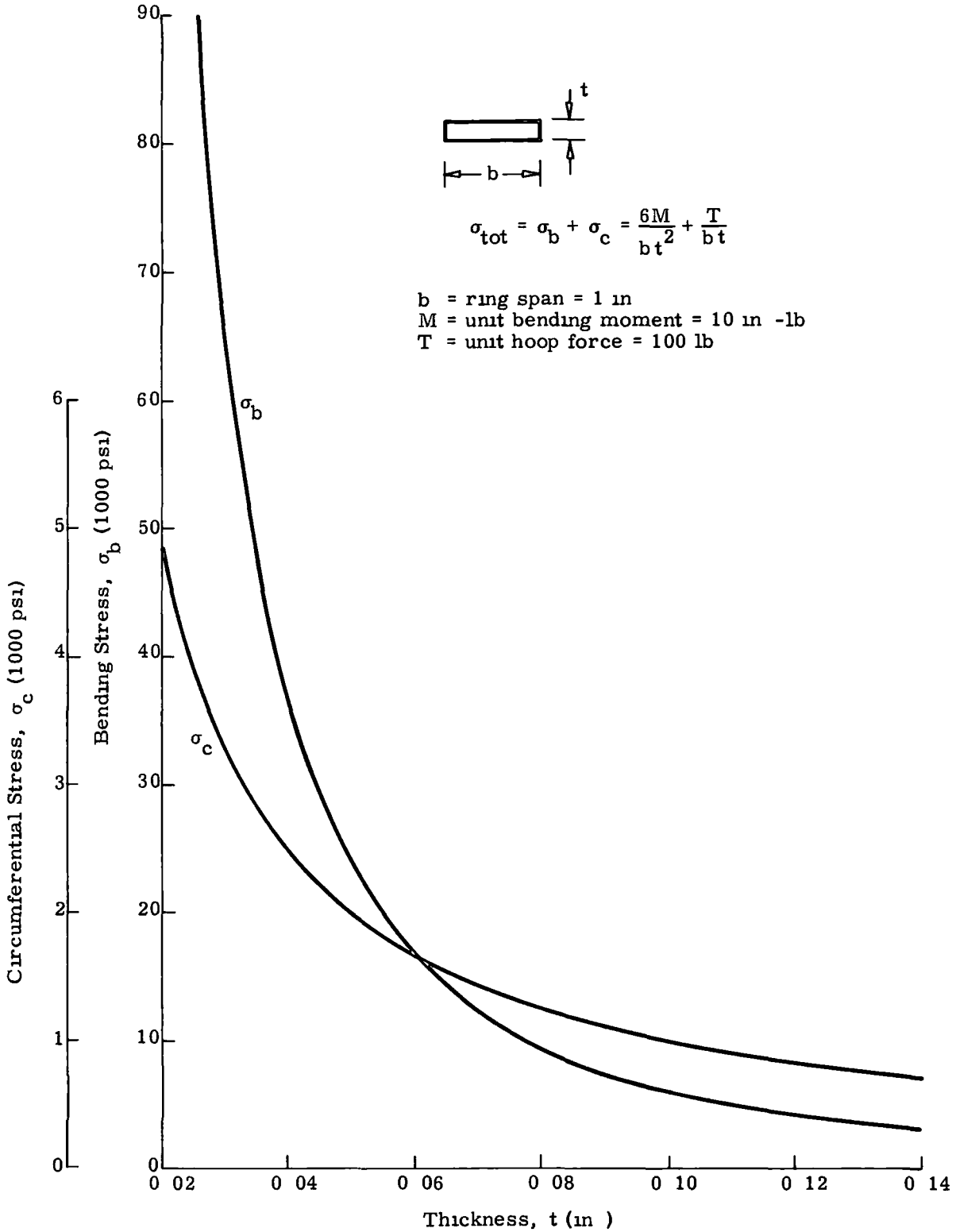


Fig 21 Bending Stress for Unit Moment and Circumferential Stress for Unit Hoop Load as a Function of Reinforcing Ring Thickness

The model used for the calculations is shown in Fig 22 One half of a quadrant of the cylinder was considered, and two-dimensional r θ calculation was performed The heat transfer coefficient at the leading edge was used (L/D = 0) The comb which was considered was 0 040 inch thick and assumed integral with the fuel stage rings so as to provide no contact resistance to heat flow No fuel was present in the support comb Table 4 shows the heat generation rates and heat transfer coefficients which were used in the analysis Table 5 presents the resulting temperatures

TABLE 4

Heat Generation Rate and Heat Transfer Coefficients, First Stage Radial Temperature Distribution

Nodes	Heat Generation Rates (Btu/hr-in ^{3})	Heat Transfer Coefficients (Btu/hr-ft^2-°F)
1 - 5	5 5 x 10^4	2800
6 - 55	2 55 x 10^6	1700
56 - 60	1 02 x 10^5	2900
61 - 76	1 02 x 10^5	2000

TABLE 5

Temperatures in First Stage Inlet Support Comb

Node	T (°F)	Node	T (°F)	Node	T (°F)	Node	T (°F)
1	725 8	20	2194	39	2186	58	-81 9
2	450 9	21	2050	40	2133	59	-84 4
3	282 0	22	2155	41	2009	60	-84 6
4	185 2	23	2185	42	2169	61	1160
5	141 2	24	2194	43	2191	62	1460
6	1666	25	2196	44	2183	63	1682
7	1914	26	2065	45	2103	64	1710
8	2043	27	2165	46	1531	65	1707
9	2108	28	2190	47	2110	66	1697
10	2135	29	2196	48	2186	67	1680
11	1938	30	2197	49	2187	68	1634
12	2069	31	2074	50	2122	69	1486
13	2125	32	2171	51	1369	70	1086
14	2148	33	2191	52	2102	71	1760
15	2157	34	2184	53	2186	72	1742
16	2023	35	2132	54	2191	73	1740
17	2136	36	2071	55	2146	74	877 8
18	2175	37	2176	56	489 7	75	1126
19	2189	38	2193	57	-45 2	76	1747

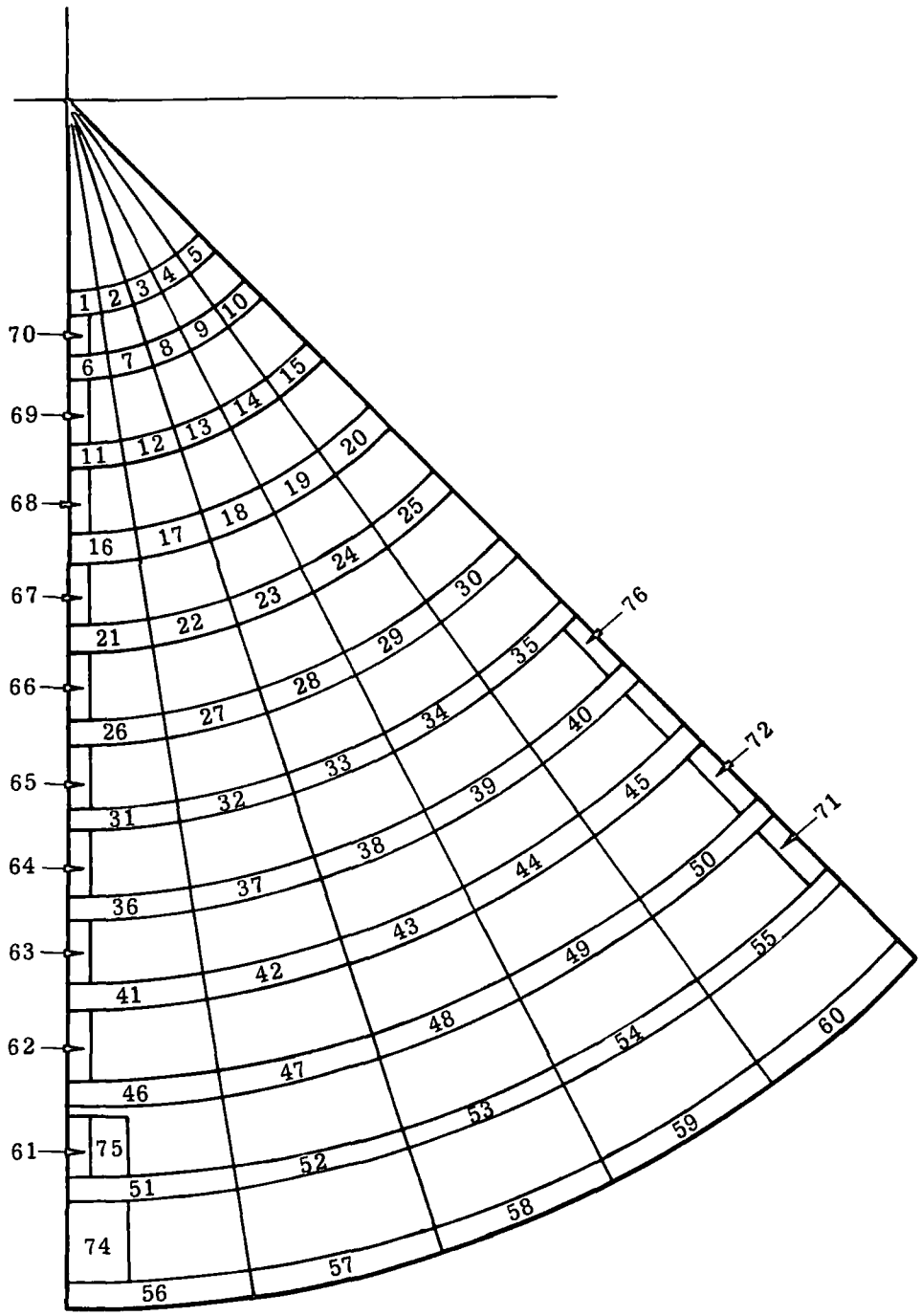
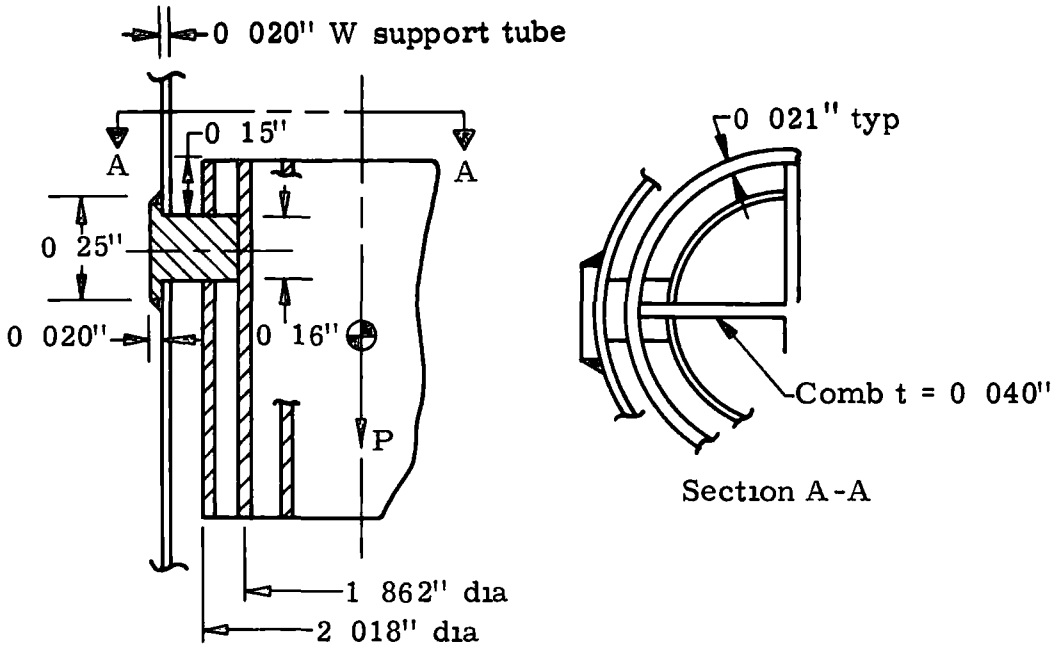


Fig 22 Fuel Stage Cross-Section Model (45-degree segment)

b Fuel stage support pins



The fuel stage support scheme is as shown in the sketch and consists of four pins symmetrically inserted The maximum load and maximum temperature of approximately 4000° F takes place at the last fuel stage near the exit end The axial load consists of inertia loading of 2 g, vibrational loading of 5 g and an axial thrust due to gas flow (see Fig 23) of about 16 5 pounds The weight of the fuel element is about one pound

$$P = 16\ 5 + 1\ (2 + 5) = 23\ 5 \text{ pounds}$$

This provides a load per pin of $\frac{23\ 5}{4}$ or 5 875 pounds

For the operational or nuclear phase, the following stress criteria and preliminary stress allowables will be employed

(1) Yield stress--80%

(2) Stress rupture for 20 hours operation

where

F_{ty} = 7000 psi for recrystallized tungsten

F_{ty} = 5000 psi for fueled tungsten

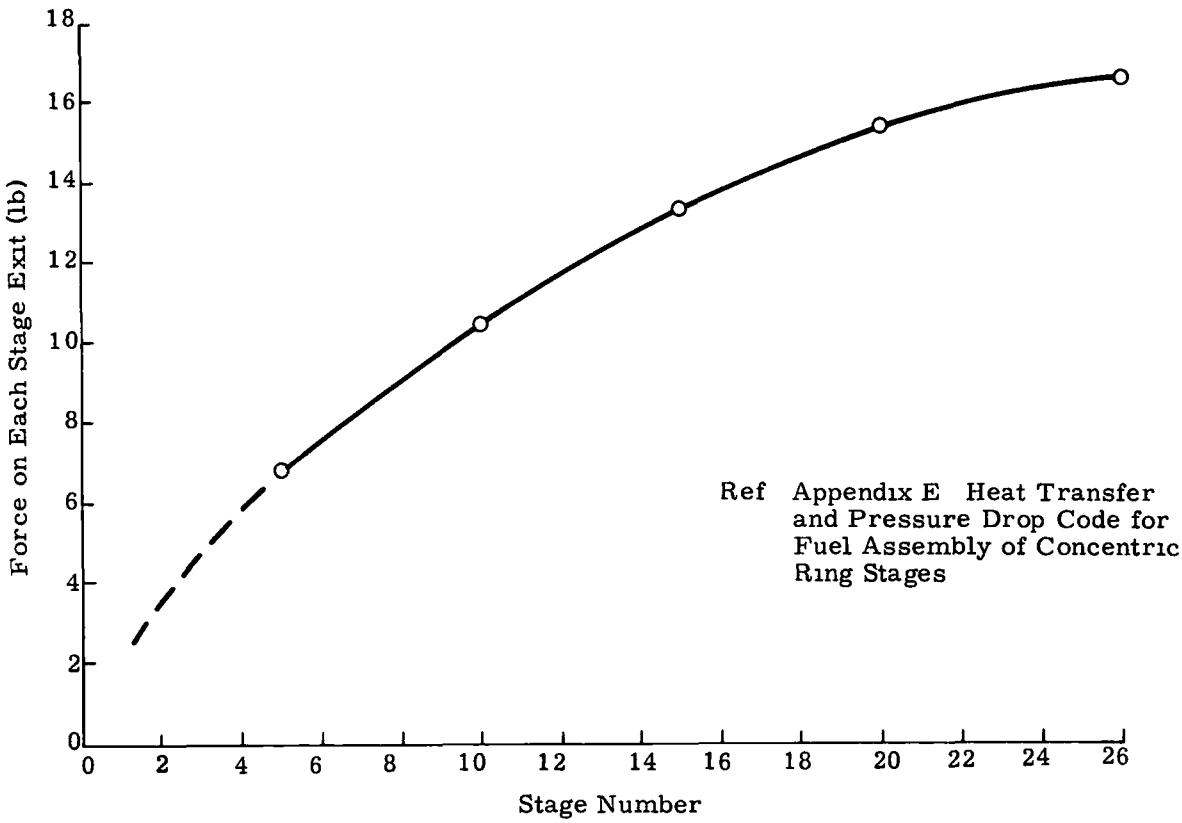


Fig 23 Total Force on Each Stage as a Function of Stage Position in Fuel Assembly

F_{SR} = 1200 psi at 20 hours for recrystallized tungsten

F_{SR} = 1050 psi at 20 hours for fueled tungsten

It will be assumed conservative to compare bearing and shear stress levels, as well as tension, to F_{SR}

The shear flow in the weld is given by the equation

$$q = \frac{P}{\pi R} \sin \phi$$

or the shear stress is

$$\tau = \frac{P}{\pi R t} = \sin \phi$$

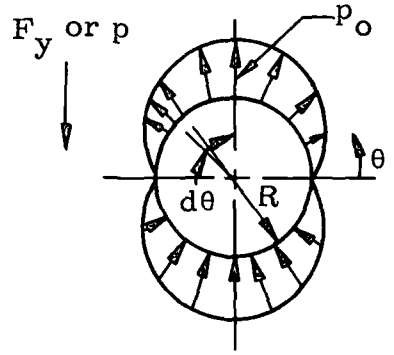
where P = 5 875 pounds, R ≅ 0 125 inch and t = the minimum weld thickness which is 0 020 (0 707) or 0 0141 inch Therefore the maximum shear stress at $\phi = \pm \pi/2$ is

$$\tau_{max} = \frac{5\ 875}{(0\ 125)\ (0\ 0141)} = 1060 \text{ psi}$$

$$MS = \frac{1200}{1060} - 1 = 0\ 13$$

The tension and compression load distribution in the support tube is assumed to act in a cosine distribution where

$$p = p_o (1 - \cos \theta)$$



The force is p(R d θ)t where the component in the y-direction becomes,

$$f_y = p R t \sin \theta d\theta$$

$$= p_o R t (\sin \theta - \tfrac{1}{2} \sin 2\theta)\, d\theta$$

or

$$F_y = \int_o^{\pi/2} 4 p_o R t (\sin \theta - \tfrac{1}{2} \sin 2\theta) d\theta$$

$$= 4 p_o R t \left[- \cos \theta + \frac{\cos 2\theta}{4} \right]_o^{\pi/2}$$

$$= 2 p_o R t$$

The maximum stress becomes p_o where

$$\sigma_{max} = p_o = \frac{F_y}{2R\,t}$$

$$= \frac{5\ 875}{2(0\ 125)(0\ 020)}$$

$$= 1175 \text{ psi}$$

$$MS = \frac{1200}{1175} - 1 = 0\ 02$$

The pin is assumed a stub beam where the expected mode of failure would be in shear

$$\tau = \frac{P}{A_s}$$

where

$$A_s = \frac{\pi(0\ 16)^2}{4} = 0\ 0201 \text{ in}^2$$

$$\tau = \frac{5\ 875}{0\ 0201} = 292 \text{ psi}$$

$$MS = \frac{1050}{292} - 1 = 3\ 60$$

The fuel element section is analyzed for bearing and shear tear out The bearing stress is given by

$$\sigma_{br} = \frac{P}{A_b}$$

where

$$A_b = \left[\frac{1}{2}(2\ 018 - 1\ 862) - 0\ 021\right] 0\ 040 + 0\ 16(0\ 021)$$

$$= 0\ 00564 \text{ in}^2$$

$$\sigma_{br} = \frac{5\ 875}{0.00564} = 1022 \text{ psi}$$

$$MS = \frac{1050}{1040} - 1 = 0\ 01$$

For shear tear out

$$\tau = \frac{P}{A_s}$$

where

$$A_s \geq 0\ 021(2)(0\ 16) + 0\ 040(0\ 16) = 0\ 0131 \text{ in}^2$$

$$\tau = \frac{5\ 875}{0\ 0131} = 449 \text{ psi}$$

$$MS = \frac{1050}{449} - 1 = 1\ 34$$

4 Exit End

a Insulation

A preliminary thermal analysis of the fuel tube exit end was made to determine what type of thermal insulation is required to maintain the aluminum tube sheet at 300° F (maximum) without excessive heat loss The results indicate that ample thermal insulation can be obtained utilizing stagnant and convective layers of hydrogen gas There appears to be no need of attaching fibrous or other forms of insulation materials to the bottom of the tube sheet

The proposed design is shown in Fig. 24 Thermal insulation is provided by two regions of hydrogen gas The outer region is formed by a flared extension of the tungsten support tube as shown The thickness of gas between inner and outer surfaces is made small enough to suppress natural convection The extension is hexagonal in cross section so that adjacent fuel tube assemblies may be butted against one another providing insulation over almost the entire bottom cross-sectional area of the core A slight gap will exist at the butted joints The inner region of hydrogen gas is actually an extension of the stagnant gas region which insulates the sides of the support tube The depth of the region is dependent upon the thermal expansion of the support tube relative to the tube sheet The calculations contained in this analysis are for a 5/8-inch gas thickness

As a first approximation, the insulation was analyzed assuming one-dimensional heat transfer between parallel plates with an intermediate gas The model is as follows

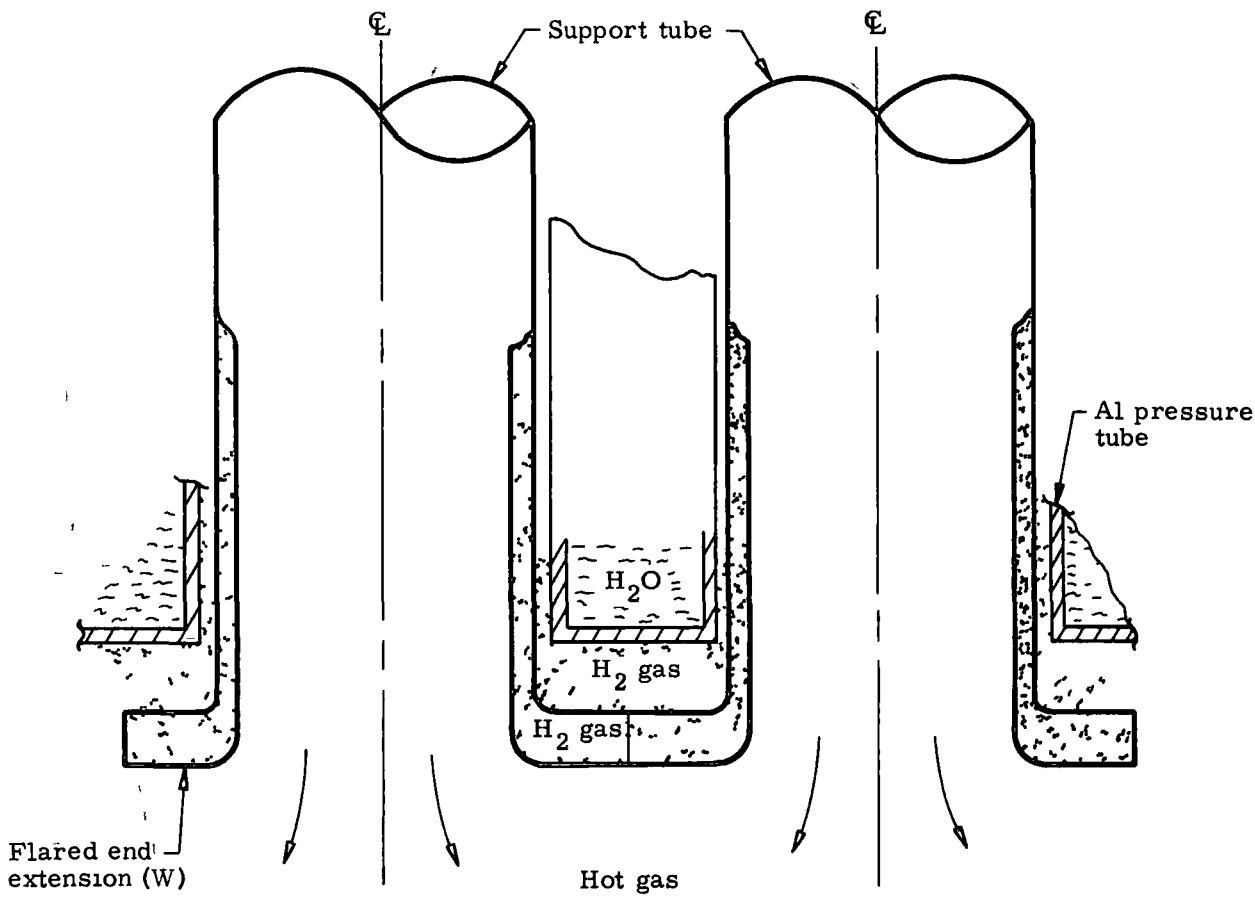
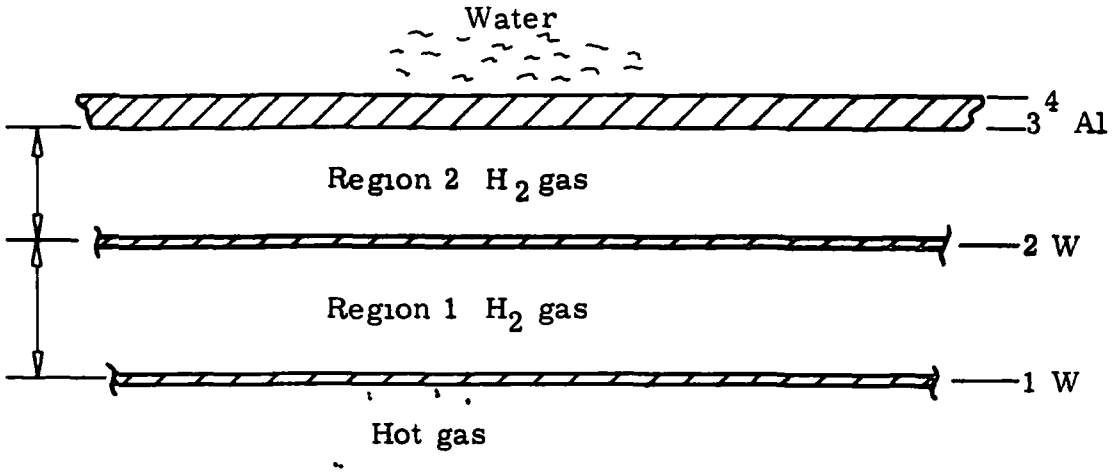


Fig 24 Exit End Insulation



For a conservative estimate, the outer tungsten plate was assumed to be at the same temperature as the hot gas (4000° F) For this analysis, heat transfer to the surrounding rocket nozzle was neglected. The effect of the gap in Region 1, created by butting adjacent fuel tubes, was also neglected for this phase of the analysis A list of the nomenclature used in this analysis follows

LIST OF NOMENCLATURE

R	Thermal resistance
k	Thermal conductivity
μ	Absolute viscosity
ρ	Mass density
c_p	Specific heat at constant pressure
β	Thermal coefficient of volume expansion, $-\frac{1}{\rho}\left(\frac{\partial \rho}{\partial T}\right)_p$
p	Pressure
x	Plate spacing
q'	Heat flux
A	Effective area for heat flow
σ	Stefan-Boltzmann constant
G_R	Grashof number
P_R	Prandtl number
T	Temperature
ΔT	Temperature difference
Q	Net heat flow per fuel tube assembly
ϵ	Emissivity

Subscripts

1, 2, 3	Refer to Surfaces 1, 2 and 3
12, 23	Refer to regions between Surfaces 1 and 2, and Surfaces 2 and 3, etc
f	Thermal properties evaluated at average film temperature.

The heat flux in Region 1 between the parallel Plates 1 and 2 is expressed by

$$q'_{12} = F_{12}\,\sigma\left(T_1^4 - T_2^4\right) + \frac{1}{R_{12}}\left(T_1 - T_2\right) \qquad (18)$$

where

$$F_{12} = \frac{1}{\frac{1}{\epsilon_1} + \frac{1}{\epsilon_2} - 1}$$

T_1 = 4000° F

T_2 = unknown

R_{12} = thermal resistance of gas for Region 1

The heat flux in Region 2 between parallel Plates 2 and 3 is expressed by

$$q'_{23} = F_{23}\,\sigma\left(T_2^4 - T_3^4\right) + \frac{1}{R_{23}}\left(T_2 - T_3\right) \qquad (19)$$

Finally, the heat flux through the aluminum tube sheet is

$$q'_{34} = \frac{T_3 - T_4}{R_{34}} \qquad (19a)$$

Preliminary calculations indicated that the resistance, R_{34}, is small in comparison to the other resistances in the model and therefore was neglected, hence, $T_3 - T_4$ It was further assumed that the tube sheet temperature on the water side is 300° F, leaving about 100° F temperature drop allowance across the water heat transfer film The internal heat generation from gamma rays and neutrons was neglected in this calculation

A heat balance between Regions 1 and 2 requires that $q'_{12} = q'_{23}$
Therefore,

$$F_{12}\sigma\left(T_1^4 - T_2^4\right) + \frac{1}{R_{12}}\left(T_1 - T_2\right) = F_{23}\sigma\left(T_2^4 - T_3^4\right) + \frac{1}{R_{23}}\left(T_2 - T_3\right) \qquad (20)$$

This equation must be solved to obtain the unknown temperature T_2
The solution is necessarily iterative since the resistances R_{12} and R_{23} depend on the gas thermal properties which in turn depend on temperature The situation is complicated since the resistances may be convective or purely conductive To establish the principal mode, the criteria of Ref 8, p 182, were used This is based on natural convection between horizontally enclosed parallel plates with heat flow upward The criteria state that natural convection is suppressed for Grashof numbers less than 1000 where the characteristic dimension is plate spacing Based on this, it was found that pure conduction exists in Region 1 for plate spacing less than 0 4 inch, and convection exists in Region 2 for a spacing of 0 625 inch

The calculations are as follows

ϵ_1 = 0 28 at T = 4000° F, W

ϵ_2 = 0 23 at T = 3100° F, W

ϵ_3 = 0 05 at T = 300° F, Al

x_{12} = 0 4 inch = 0 033 foot (Region 1)

x_{23} = 0 625 inch = 0 052 foot (Region 2)

k_{12} = 0 45 Btu/hr-ft-°F at 3550° F, H_2 gas

k_{23} = 0 288 Btu/hr-ft-°F at 1700° F, H_2 gas

$$F_{12} = \frac{1}{\frac{1}{\epsilon_1} + \frac{1}{\epsilon_2} - 1} = \frac{1}{\frac{1}{0\ 28} + \frac{1}{0\ 23} - 1} = 0\ 144$$

$$F_{23} = \frac{1}{\frac{1}{\epsilon_2} + \frac{1}{\epsilon_3} - 1} = \frac{1}{\frac{1}{0\ 23} + \frac{1}{0\ 05} - 1} = 0\ 043$$

To calculate R_{23}, the correlation by Jakob for natural convection in a horizontal enclosed space will be used (Ref 8, p 182)

$$\frac{h'_c x}{k_f} C \left[\frac{x^3 \rho_f^2 g \beta_f \Delta T}{\mu_f^2} \left(\frac{c_p \mu}{k} \right)_f \right]^n \qquad (21)$$

In order to obtain C and n in this equation, the Grashof number, G_R, must be calculated

$$G_R = \frac{x^3 \rho_f^2 g \beta_f \Delta T}{\mu_f^2}$$

For $10,000 \leq G_R \leq 3\ 2(10)^5$, $C = 0\ 21$, $n = 1/4$ in Eq (21)

Evaluating the various components of G_R for Region 2

$$\Delta T = T_2 - T_3 = 3100^\circ F - 300^\circ F = 2800^\circ F$$

$$T_f = \frac{T_2 + T_3}{2} = 1700^\circ F\ (2160^\circ R)$$

Note that T_3 was found by iteration from Eq (20)

$$\mu_f = 15\ 16 \times 10^{-6}\ lb/ft\text{-}sec$$

$$\beta_f = \frac{1}{T_f} = \frac{1}{2160} = 0\ 000463/^\circ R$$

$$\rho_f = \frac{P}{RT} = \frac{600\ lb/in^2 \times 144\ in^2/ft^2}{767\ 5\ ft\text{-}lb/lb\text{-}^\circ R \times 2160^\circ R} = 0\ 052\ lb/ft^3$$

$$g_x = 2 \times 32\ 2\ ft/sec^2 = 64\ 4\ ft/sec^2$$

Note that a 2-g sustained acceleration was assumed

$$c_p = 3\ 68\ Btu/lb\text{-}^\circ F$$

$$k_f = 0\ 288\ Btu/hr\text{-}ft\text{-}^\circ F$$

$$P_R = \frac{\mu_f c_p}{k_f} = \frac{15\ 16 \times 10^{-6} \times 3\ 68 \times 3600}{0\ 288} = 0\ 7$$

$$G_R = \frac{0.052^3 \times 0\ 052^2 \times 64.4 \times 4\ 63 \times 10^{-4} \times 2800}{15\ 16^2 \times 10^{-12}}$$

$$\frac{[ft^3]\ [lb^2/ft^6]\ [ft/sec^2]\ [1/°R]\ [°R]}{[lb^2/ft^2\text{-}sec^2]}$$

G_R = 139,000, therefore, C = 0 21, n = 1/4

Therefore

$$\frac{h'_c x_{23}}{k_f} = 0\ 21\ [139,000 \times 0\ 70]^{1/4} = 3\ 7$$

$$h'_c = 3\ 7 \frac{k_f}{x_{23}} = \frac{3.7 \times 0\ 288}{0\ 052}$$

$$h'_c = 20\ 5\ Btu/hr\text{-}ft^2\text{-}°F$$

$$R_{23} = \frac{1}{20\ 5} = 0\ 0487\ hr\text{-}ft^2\text{-}°F/Btu$$

The spacing x_{23} for Region 2 could be made smaller since the calculated axial differential expansion between the tungsten support tube and the core assembly is about 0 32 inch For x_{23} = 0 32, however, G_R = 18,700 and C, n in Eq (21) are still 0 21 and 1/4, respectively Further, since h'_c is proportional to $x^{-0\ 25}$, the heat transfer coefficient would in fact be higher at a reduced spacing For this reason, there is no thermal advantage in reducing the spacing below 0 625

In order to verify that convection is suppressed in Region 1, the Grashof number must be less than 1000 For Region 1,

T_1 = 4000° F

T_2 = 3100° F

T_f = 3550° F(4010° R)

$x_{12} = \frac{0\ 4}{12}$ = 0 033 foot

μ_f = 22 68 x 10^{-6} lb/ft-sec

$$\beta_f = \frac{1}{T} = \frac{1}{4010} = 2\ 5 \times 10^{-4}\ 1/°R$$

$$\rho_f = \frac{P}{RT} = \frac{600 \times 144}{767\ 5 \times 4010} = 0\ 028\ lb/ft^3$$

$$G_R = \frac{x_{12}^3 \rho_f^2 g \beta_f \Delta T_{12}}{\mu_f^2}$$

$$= \frac{0.033^3 \times 0\ 028^2 \times 64\ 4 \times 2.5 \times 10^{-4} \times 900}{22\ 68^2 \times 10^{-12}}$$

$$G_R = 820 \text{ at } 2 \text{ g acceleration}$$

Therefore, convection is suppressed

Substituting the various parameters into Eq (20) yields

$$0.144 \times 0\ 1714 \left[\left(\frac{4460}{100}\right)^4 - \left(\frac{T_2}{100}\right)^4\right] + \frac{0\ 45}{0.033}(4460 - T_2)$$

$$= 0\ 043 \times 0\ 1714 \left[\left(\frac{T_2}{100}\right)^4 - \left(\frac{760}{100}\right)^4\right] + 20\ 5\ \left[T_2 - 760\right]$$

Solving this equation yields

$$T_2 = 3580° \text{ or } 3120° F$$

Now the heat flux can be calculated for each region

$$q'_{12} = F_{12}\sigma\left(T_1^4 - T_2^4\right) + \frac{1}{R_{12}}(T_1 - T_2)$$

$$= 0\ 144 \times 0\ 1714 \left[\left(\frac{4460}{100}\right)^4 - \left(\frac{3580}{100}\right)^4\right] + \frac{0\ 45}{0\ 033}(4460 - 3580)$$

$$= 58,200 + 12,000$$

$$q'_{12} = 70,200 \text{ Btu/hr-ft}^2$$

$$q'_{23} = F_{23}\sigma\left(T_2^4 - T_3^4\right) + \frac{1}{R_{23}}\left(T_2 - T_3\right)$$

$$= 0.043 \times 0\ 1714\left[\left(\frac{3580}{100}\right)^4 - \left(\frac{760}{100}\right)^4\right] + 20.5\,[3580 - 760]$$

$$= 12,200 + 58,000$$

$$q'_{23} = 70,200 \text{ Btu/hr-ft}^2$$

The results for q'_{12} and q'_{23} show that in Region 1, approximately 83% of the heat is transferred by radiation with the remaining 17% transferred by conduction This indicates that the heat flux could be reduced by the placement of additional radiation shields in Region 1 However, as it will be subsequently shown, this is probably not worth the effort since the heat flow is already a negligible value

In Region 2, the situation is reversed in that practically all the heat is transferred by convection In this region, heat flux could be reduced by providing a resistance next to the aluminum tube sheet in the form of a powder, foam or fibrous sheet However, here again, it does not appear justified

The net heat loss out the bottom of a typical fuel assembly is calculated based on a hexagonal shape with a concentric hole as shown in Fig 25

$$A = A_{hex} - A_{circle}$$

$$= 6\,[1/2 \times 1\ 82 \times 1.578] - \frac{\pi}{4}(2.14)^2$$

$$= 5 \text{ in}^2$$

Heat loss per fuel assembly is

$$Q = q'\,A$$

$$= 70,200 \text{ Btu/hr-ft}^2 \times 5 \text{ in}^2 \times \frac{1}{144} \text{ ft}^2/\text{in}^2$$

$$= 2440 \text{ Btu/hr}$$

$$Q = 0\ 68 \text{ Btu/sec}$$

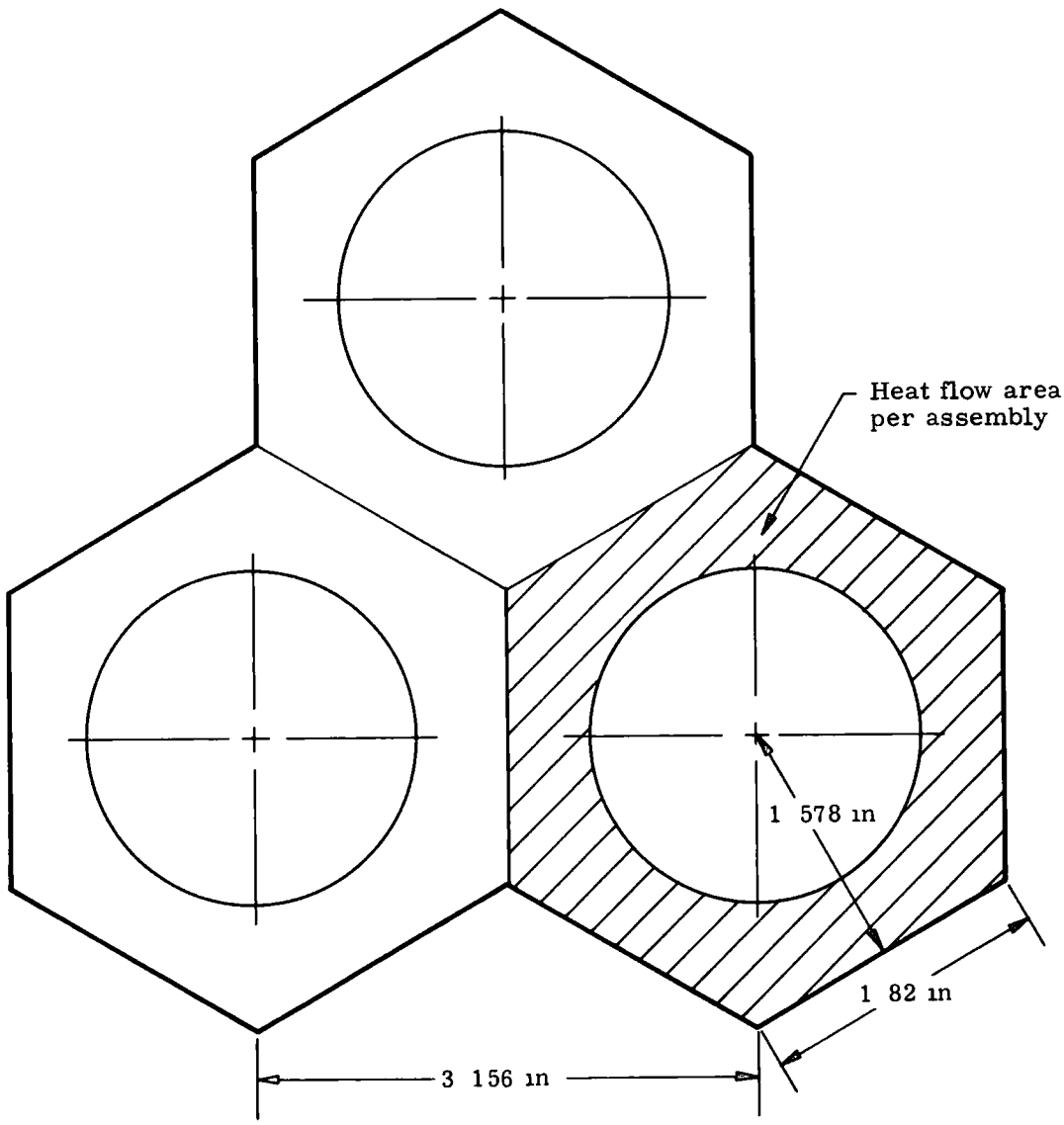


Fig 25 Fuel Assembly Spacing

Considering that the total heat generated per fuel tube is of the order of 15,000 Btu/sec, this is an insignificant heat loss

A problem area of potentially greater concern lies in heat removal from the aluminum exit tube sheet while limiting maximum aluminum temperature to about 300° F The available coolant flow is moderator water which must be turned 90 degrees at the tube sheet and removed from the core at the core outer diameter. The heat transfer coefficient available on the tube sheet surface between fuel assemblies is, of course, important design data, and an estimate of the coefficient necessary can be calculated

Assuming that the effective cooling surface between tubes is that outside the water annulus outer diameter of 2.7 inches, the heat flux previously calculated as 70,200 becomes 123,000 Btu/hr-ft^2 Q (Btu/hr) = $hA\Delta T_f$, and $\frac{Q}{A}$ = 123,000 Btu/hr-ft^2, where ΔT_f is the film temperature drop between the aluminum surface and the bulk water temperature, A is the effective heat transfer area, and h is the heat transfer coefficient Then the heat transfer coefficient necessary to obtain a given film drop is h = $\frac{123,000}{\Delta T_f}$ Btu/hr-ft^2-°F To limit the film drop to 40° F, an h of 3080 is required Based on a bulk water temperature of 240° to 280° F, this would effectively prevent excessive temperature in the aluminum tube sheet

Inserting h = 3100 in the Dittus-Boelter correlation for turbulent flow heat transfer, and assuming a typical flow passage equivalent diameter of one inch, a typical required flow velocity is 9 25 fps This rough check on the flow requirement is considered indicative of feasibility

b Radial temperature distributions in exit end supports

Temperature distributions were obtained for two simple support designs These designs are shown in Figs. 6 and 7, the reference and alternate design drawings. The components of each design are constructed of the same material but they are of differing geometrical configurations Both concepts rely on a ceramic insulating material to prevent heat flow from the tungsten liner to the aluminum pressure tube and to provide structural integrity under the applied loads. The heat transfer models for both configurations are shown in Figs 26 and 27

In both configurations, a columbium insert is pressed into the aluminum pressure tube to provide increased strength The stainless steel used in the reference design would decrease the heat flow through the system, raising the ceramic temperature somewhat Zirconia

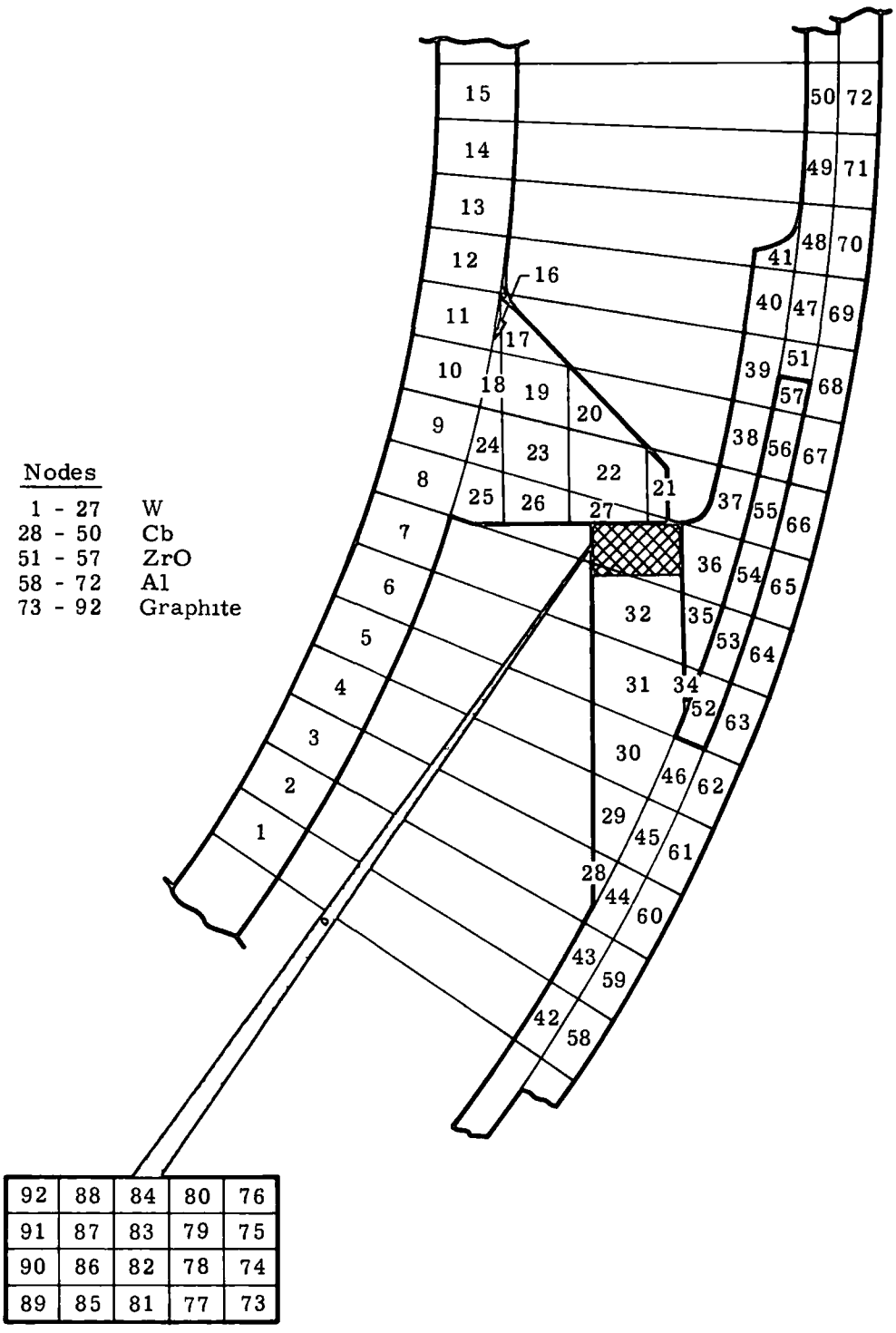


Fig 26 Exit End Simple Support--Dual Lug

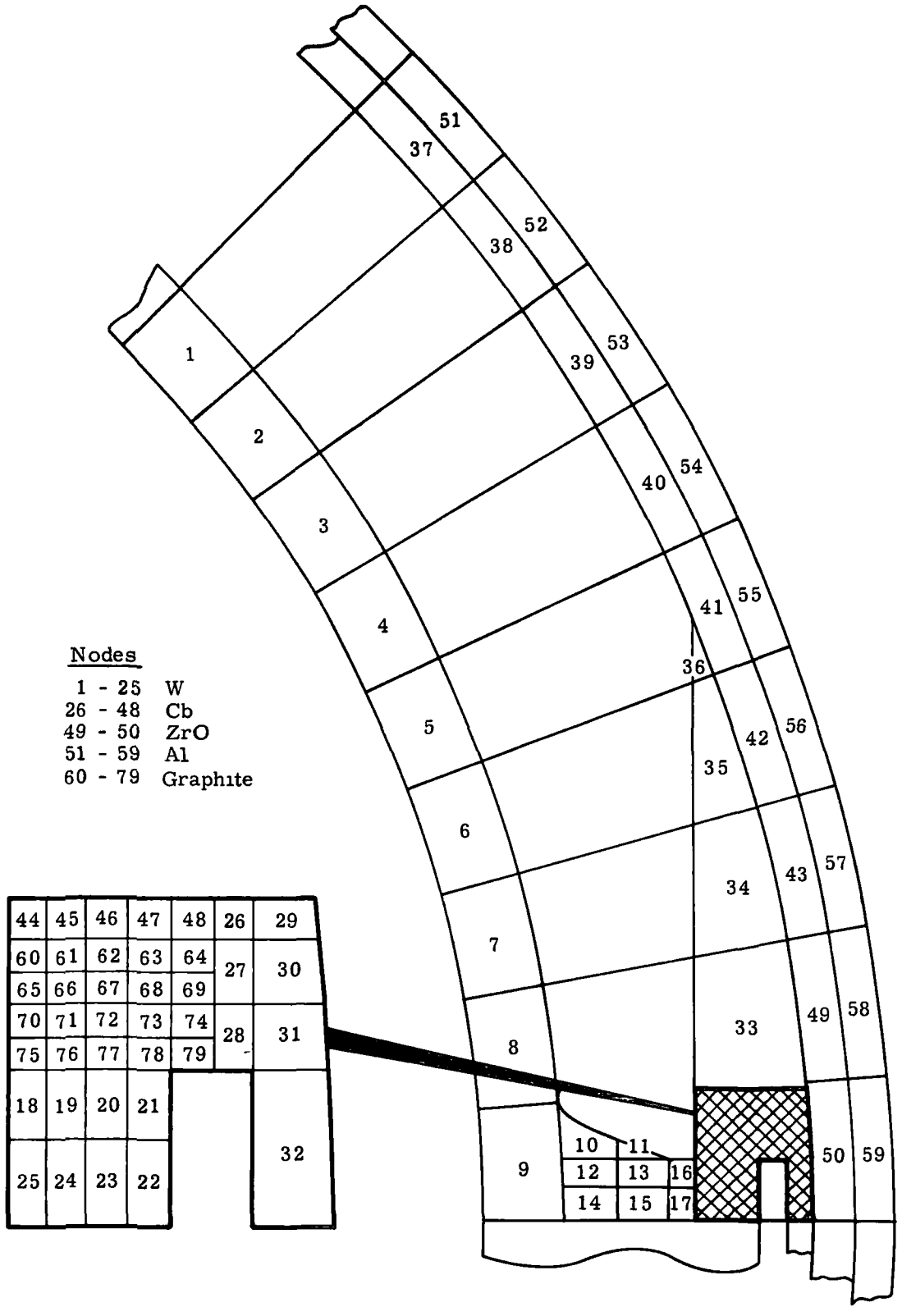


Fig 27 Exit End Simple Support--Single Lug

inserts are provided between the columbium and aluminum to provide additional insulation for the aluminum Pyrolytic graphite is used between the tungsten and columbium as a heat barrier The low conductivity direction of the graphite is oriented between the tungsten and columbium since the hydrogen gap provides effective thermal insulation where there is no contact between the two metals Table 6 presents the heat generation rates and thermal conductivities that were used in the calculations Boundary temperatures of 4000° and 240° F were used for the hot gas and cooling water temperatures, respectively Heat transfer coefficients of 2000 and 4000 Btu/hr-ft^2-°F were used for the gas and water The emissivity of tungsten was taken as 0 23 and the emissivity of columbium that was used was 0 15 Calculated temperatures at each node location are shown in Table 7 and 8 for the two configurations An infinite heat transfer coefficient was assumed between the ceramic on the lug and the columbium insert.

TABLE 6

Material Heat Generation Rates and Thermal Conductivities for Exit End Simple Supports

Material	Heat Generation (Btu/hr-in^3)	Thermal Conductivity (Btu/hr-ft-°F)
Tungsten	1 37 x 10^4	55 0
Zirconia	2 52 x 10^3	0 55
Columbium	4 62 x 10^3	35 0
Aluminum	1 20 x 10^3	106 0
Pyrolytic graphite (c direction)	8 68 x 10^2	0 65
(a, b directions)		105.0
Hydrogen	--	0 275

c Exit end support stresses

An exit end support which has four pairs of lugs was considered The lugs are built into a circumferential ring which is brazed to the support tube exit end. For this analysis, the geometry used for developing lug loads, ring moments and hoop forces is given in the sketch This figure gives the approximate lug reinforcing ring geometry and typical dimensions of a lug

TABLE 7

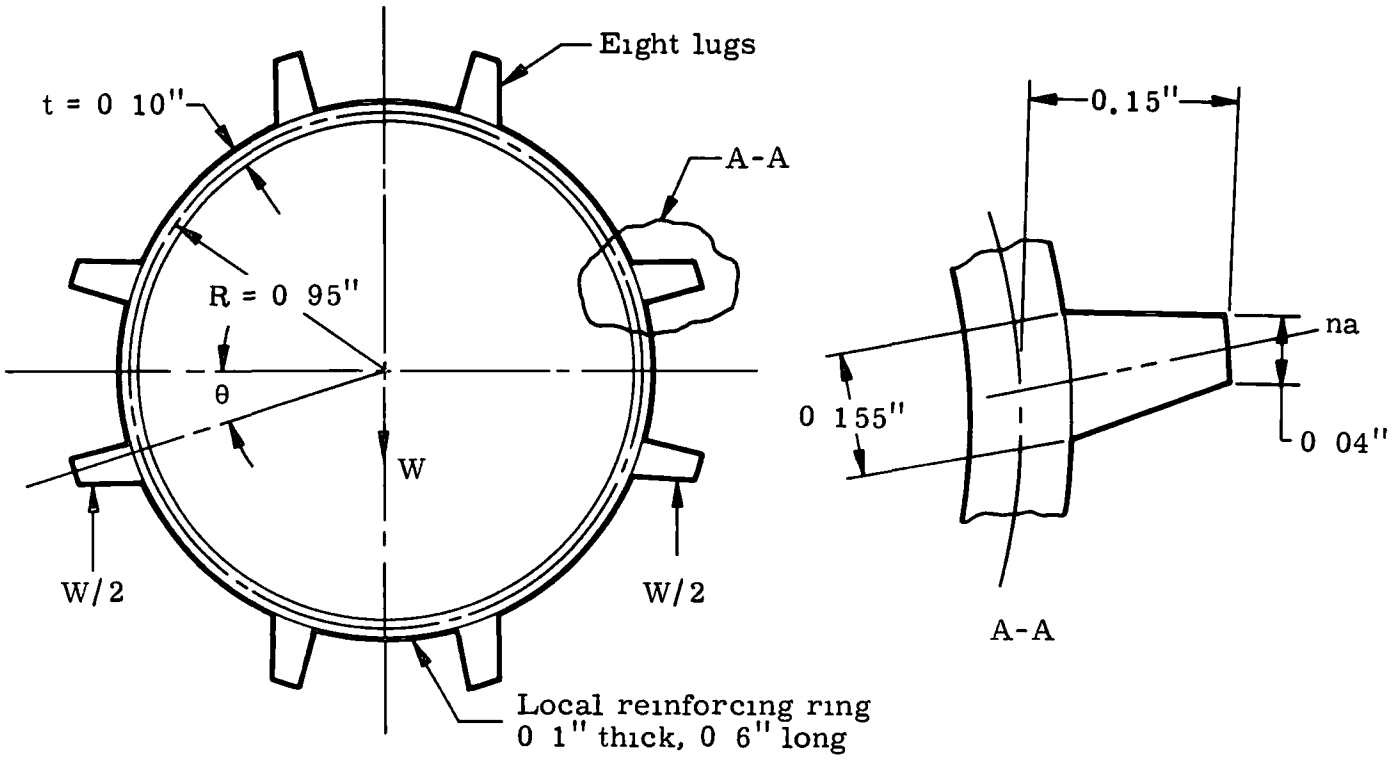
Exit End Simple Support (Fig. 26)

Node	Temperature (°F)	Node	Temperature (°F)
1	3976.058	47	316 312
2	3975 533	48	309 671
3	3974 445	49	304 505
4	3975.363	50	302 620
5	3976 483	51	322 006
6	3977 825	52	362 591
7	3979 928	53	370 660
8	3982 400	54	373 234
9	3982 878	55	395 676
10	3982 187	56	388 601
11	3981.586	57	357 879
12	3981 657	58	296 710
13	3981 891	59	298 524
14	3982 108	60	301.973
15	3982 213	61	303 408
16	3966 904	62	300 381
17	3961 580	63	284 739
18	3968 976	64	276.899
19	3960 903	65	274.465
20	3945 332	66	276 687
21	3927 855	67	283 431
22	3943 228	68	296 764
23	3962 775	69	302 304
24	3972 770	70	300 183
25	3974 177	71	297 069
26	3964.237	72	295 474
27	3945.043	73	417 907
28	322 347	74	1905 388
29	334 035	75	2653.333
30	355 832	76	3223 082
31	392 712	77	418 451
32	407 997	78	1939 784
33	409.587	79	2695 209
34	396.310	80	3280 309
35	406.093	81	420.320
36	409.698	82	1980 703
37	460 418	83	2736 591
38	440 227	84	3326 674
39	372 937	85	427 643
40	333 603	86	2028 600
41	325 988	87	2777 425
42	303 905	88	3362.920
43	306.105	89	457 913
44	312 373	90	2084 035
45	315 566	91	2817 681
46	317 222	92	3389 845

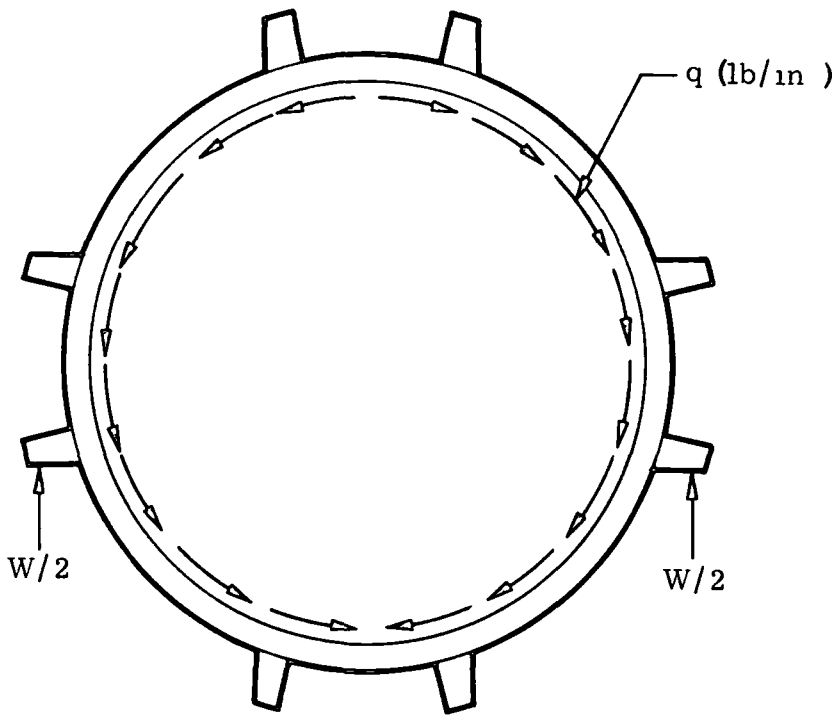
TABLE 8

Exit End Simple Support (Fig 27)

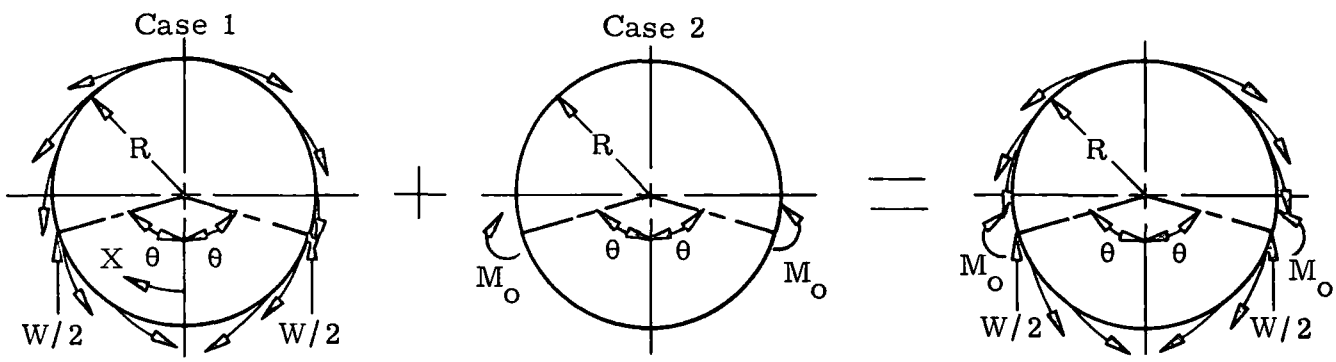
Node	Temperature (°F)	Node	Temperature (°F)
1	3922 133	41	292 964
2	3921 694	42	302 934
3	3920 678	43	310 105
4	3918 770	44	415 358
5	3915 374	45	413 581
6	3909 956	46	413 319
7	3906 229	47	414 277
8	3904 662	48	417 517
9	3906 768	49	360 619
10	3897 099	50	403 534
11	3890 508	51	273 742
12	3897 618	52	274 173
13	3884 829	53	275 396
14	3897 421	54	278 432
15	3881 781	55	285 656
16	3863 166	56	293 462
17	3862 375	57	295 285
18	3848 489	58	269 171
19	3838 056	59	262 749
20	3827 172	60	1367 825
21	3815 812	61	1385 112
22	3815 763	62	1396 900
23	3827 100	63	1404 242
24	3837 920	64	1407 787
25	3848 202	65	3654 903
26	426 642	66	3581 519
27	445 985	67	3528 035
28	452 141	68	3493 104
29	433 668	69	3475 854
30	466 666	70	3881 569
31	459 966	71	3876 562
32	546 028	72	3872 239
33	408 760	73	3869 101
34	348 512	74	3867 461
35	321 152	75	3898 042
36	302 664	76	3901 106
37	279 743	77	3903 441
38	280 194	78	3905 437
39	281 475	79	3907 469
40	284 682		



In this analysis the support tube adjacent to the lug reinforcing ring is conservatively neglected with respect to providing any additional support The vertical load imposed by the tube on the lug supports is assumed to act as a shear flow through the reinforcing ring and to be reacted vertically by two lug supports A sketch of this load distribution is shown



The moment and hoop force distribution in the ring shall be determined by the method of superposition based on a unit load (W/2 = 1 lb) as follows



The moment distributions are

Case 1 (Ref 9, p 162, Table VIII, Case 25)

from $X = 0°$ to $X = \theta$

$$M_x = WR\left[0\ 23868\,u - 1/2\,S + 0\ 15915(xz + \theta s + c - uc^2)\right]$$

from $X = \theta$ to $X = \pi$

$$M_x = WR\left[0\ 23868\,u - 1/2\,z + 0\ 15915(xa + \theta s + c - uc^2)\right]$$

Case 2 (Ref. 9, p 156, Table VIII, Case 4)

from $X = 0°$ to $X = \theta$

$$M_x = M_o\left[0\ 3183(2us + \theta) - 1\right]$$

from $X = \theta$ to $X = \pi$

$$M_x = M_o\left[0\ 3183(2us + \theta)\right]$$

where

$R = 0\ 95$ inch

$W/2 = 1$ pound

$M_o = W/2\ (0\ 15) = 0\ 15$ in -lb

$\phi = 12°,\ 48'$

$\theta = 90 - \phi = 70°,\ 12' = 1\ 3474$ rad

$s = \sin\theta = 0\ 97515$

$c = \cos\theta = 0\ 22155$

$u = \cos x$

$z = \sin x.$

The resultant component and combined moment distributions are shown in Fig 28

From Fig 28, the maximum ring moment occurs at $X = \theta = 77°,\ 12'$ and for the unit load $W/2 = 1$ pound is

$$M_{max} = 0\ 1172 \text{ in -lb}$$

The corresponding hoop force (T) at $X = 77°,\ 12'$ is as follows

Case 1

$$T = W\left[0\ 15915(xz - uc^2) - 0\ 07958\,u\right]$$

$$T = 0\ 37934 \text{ pound}$$

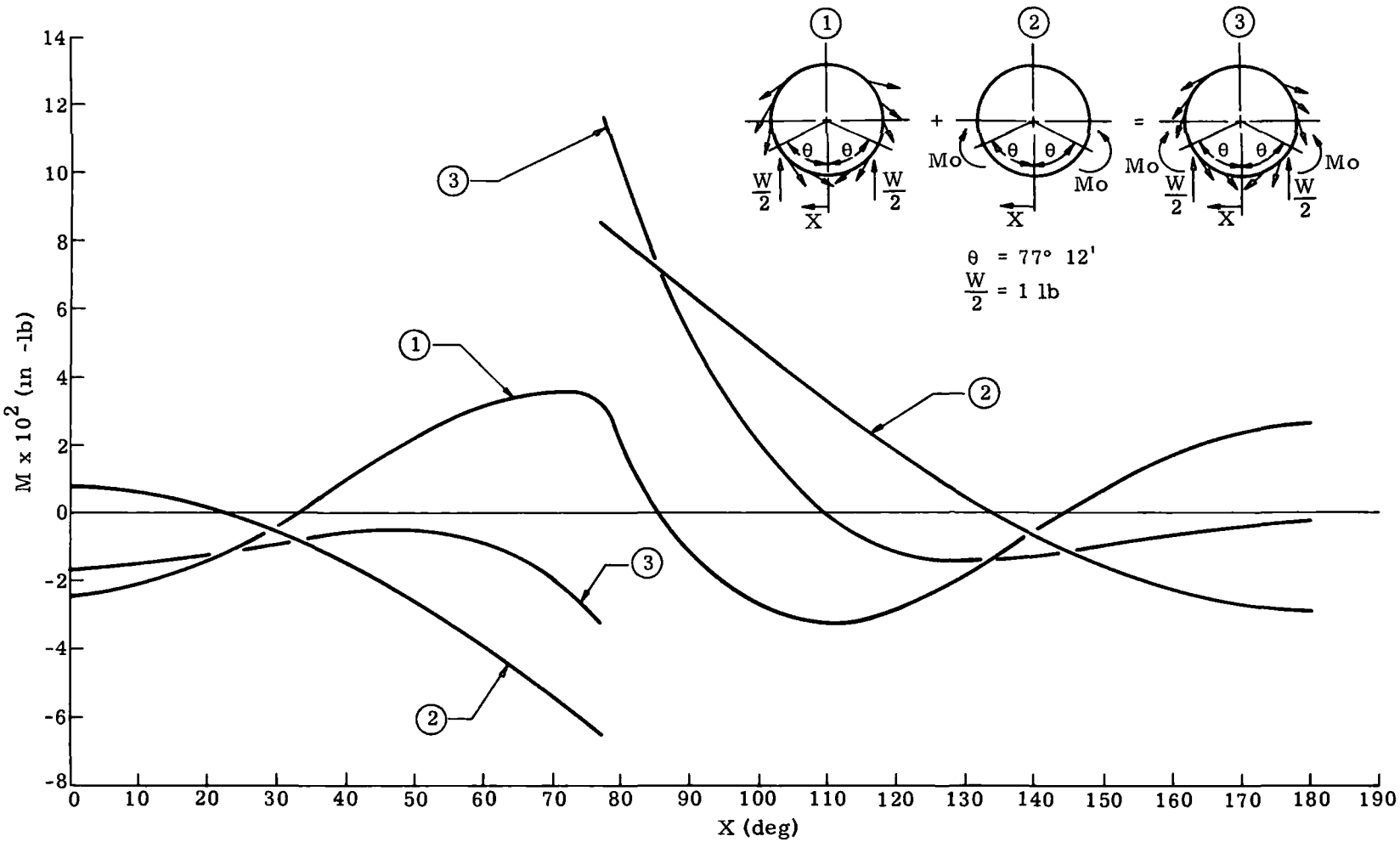


Fig 28 Moment Distribution in Reinforcing Ring at Exit End for a Unit Load

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Case 2

$$T = \frac{M_o}{R}(0.6366\ us)$$

$$T = 0\ 02171 \text{ pound}$$

thus

$$T_{tot} = \Sigma T = 0\ 40105 \text{ pound}$$

An example problem is now presented to illustrate how the reinforcing ring maximum stresses are obtained

W = assumed total lateral force = 100 pounds

$W/2$ = 50 pounds

hence, the maximum moment and hoop forces are

$$M_{max} = 0\ 1172(50) = 5\ 86 \text{ in -lb}$$

$$T = 0\ 40105(50) = 20\ 05 \text{ pounds}$$

The ring cross section is assumed as shown

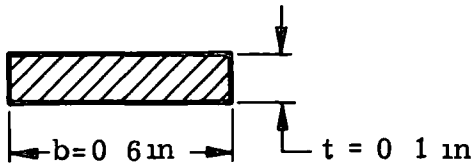


Figure 21 may be used to determine the ring bending stress (σ_b) and hoop stress (σ_c) by adjusting for the ring span (b) and actual loading by proportioning as follows For t = 0 1 inch

σ_b = stress from Fig 21 x moment ratio x span ratio

$$= 6000\left(\frac{5.86}{10}\right)\left(\frac{1}{0\ 6}\right)$$

$$= 5860 \text{ psi}$$

σ_c = stress from Fig 21 x hoop force ratio x span ratio

$$= 1000\left(\frac{20.05}{100}\right)\left(\frac{1}{0\ 6}\right)$$

$$= 335 \text{ psi}$$

Thus, the combined stress (σ_{tot}) is

$$\sigma_{tot} = \sigma_b + \sigma_c = 6195 \text{ psi}$$

d Lug evaluation

The lug and reinforcing ring material is assumed to be tungsten-25% rhenium (W-25%Re) alloy at an operating temperature of 4000° F A plot of ultimate tensile strength (σ_{tu}) of arc cast W-25%Re as a function of temperature is shown in Appendix A of this report

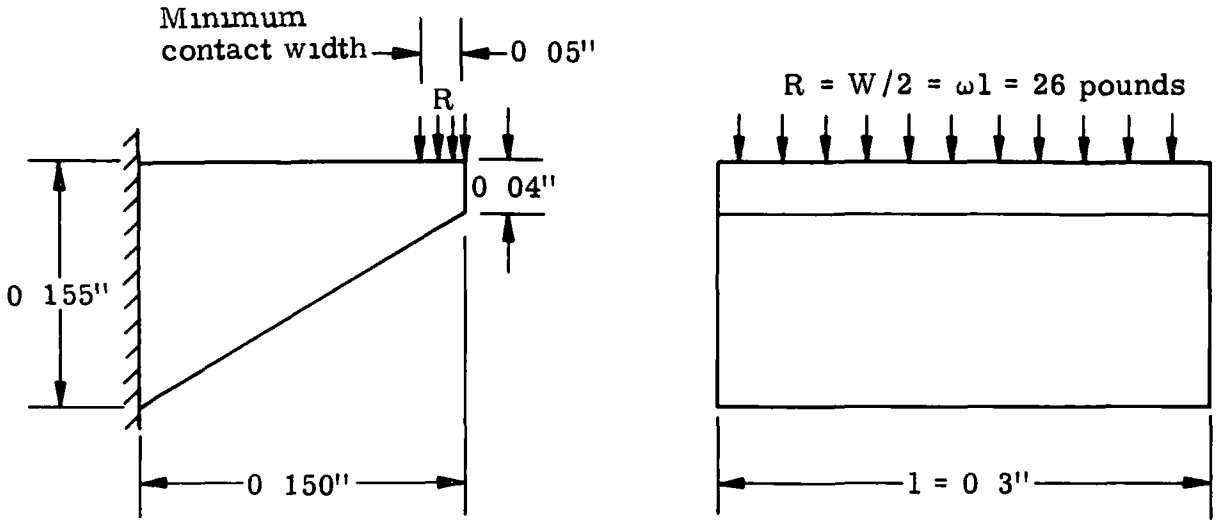
Based on the available data (from 70° to 2400° F), the ratio of yield tensile strength (σ_{ty}) to ultimate tensile strength (σ_{tu}) is 0 9 From the tensile data at 4000° F, σ_{tu} = 9000 psi (conservative extrapolation), thus, $\sigma_{ty} = 0\ 9\ \sigma_{tu}$ = 8100 psi In addition, it is assumed that the ultimate bearing strength (σ_{bru}) is 1 5 σ_{tu} and the ultimate shear strength (σ_{su}) is 0 6 σ_{tu}, hence, the following allowable stress values (for short time loading) are shown

S_{a_t} = allowable tensile strength = 0 6 σ_{ty}
= 4860 psi

S_{a_b} = allowable bearing strength = 2/3 σ_{bru}
= 9000 psi

S_{a_s} = allowable shear strength = 2/3 σ_{su}
= 3600 psi

For this analysis a total lug load of W = 52 pounds was assumed (based on a 10-g lateral load factor in a system with four spring supports and a simple support on the support tube exit end, Ref 10, para 1 2 1) The lug geometry and loading are shown in the sketch



The bearing stress in the lug is determined by

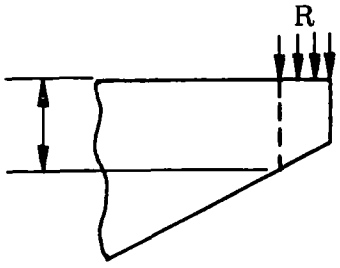
A_{br} = bearing area = 0 05(0 3) = 0 015 in ^{2}

σ_{br} = bearing stress = $\frac{R}{A_{br}}$ = 1740 psi

MS = margin of safety = $\frac{S_{a_{br}}}{\sigma_{br}}$ - 1 = 4 17

Note The ceramic interface bearing on the lug will have the same compressive area as the lug, thus, the maximum compressive stress in the ceramic will be the same as the lug bearing stress

Shear stress in lug



t_s = critical shear thickness

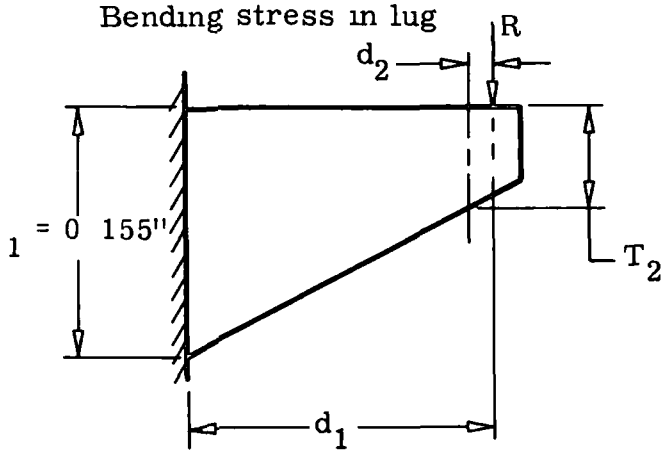
t_s = 0 040 + 0 050$\left(\frac{0.115}{0\ 150}\right)$ = 0 078 inch

A_s = shear area = t_s l = 0 0234 in ^{2}

σ_s = shear stress = $\frac{R}{A_s}$ = 1110 psi

MS = $\frac{S_{a_s}}{\sigma_s}$ - 1 = 2 24

Bending stress in lug



Loading assumed concentrated at center of bearing area

σ_b = bending stress = $\frac{6M}{bt^2}$

where

b = 0 3 inch

M = Rd

$d_1 = 0\ 150 - \frac{0\ 05}{2} = 0\ 125$ inch

$t_1 = 0\ 155$ inch

$d_2 = 0\ 025$ inch

$t_2 = 0\ 04 + 0\ 05\left(\frac{0\ 115}{0\ 150}\right) = 0\ 078$ inch

Thus, at the ring

$$\sigma_b = \frac{6Rd_1}{bt_1^2} = 2710 \text{ psi}$$

$$MS = \frac{S_{at}}{\sigma_b} - 1 = 1\ 79$$

and at location d_2 (end of bearing load)

$$\sigma_b = \frac{6Rd_2}{bt_2^2} = 2150 \text{ psi}$$

$$MS = \frac{4860}{2150} - 1 = 1.26$$

5 Lateral Support System

a Spring design temperature distribution

Thermal analyses of spring designs for the fuel assembly have been completed

The thermal analysis was performed (with exceptions as noted) using the TIGAMM digital computer code Two-dimensional heat conduction was considered with forced convection and radiation to the adjacent constant temperature boundaries The structures were subdivided into regions or nodes which were small enough to ensure reasonable accuracy The effect of internal heat generation in the structure was considered in the analysis The following paragraphs describe the analysis of each major spring type The helical spring plunger assembly is shown as the reference design in Fig 6

This assembly consists of an Inconel spring acting through a zirconium oxide plunger The entire assembly is enclosed in an aluminum shell which is welded to the aluminum pressure tube High velocity cooling water removes heat from the assembly.

The geometry which was analyzed is shown in Fig 29 In the analysis, the spring was replaced by an Inconel column of equivalent length-to-area ratio in the center of the assembly The numbers on the drawing indicate the internal nodes Surface and boundary nodes were omitted from the figure for clarity Nodal dimensions and temperatures are given in Table 9

TABLE 9

Helical Spring Plunger Nodal Dimensions and Temperatures

Node	r_2 (in)	r_1 (in)	h (in.)	T (°F)	Node	r_2 (in)	r_1 (in)	h (in.)	T (°F)
1	0 0235	0 000	0 030	208 8	31	0 0545	0 0235	0 030	1913
2	0 0545	0 0235	0 030	205 8	32	0 109	0 0545	0 030	1454
3	0 109	0 0545	0 030	203 7	33	0 0235	0 000	0 015	1674
4	0 150	0 109	0 030	202 1	34	0 0545	0 0235	0 015	1604
5	0 170	0 150	0 030	201 2	35	0 109	0 0545	0 015	1256
6	0 170	0 150	0 0567	204 4	36	0 0235	0 000	0 020	1394
7	0 170	0 150	0 0567	210 1	37	0 0545	0 0235	0 020	1417
8	0 170	0 150	0 0567	220 6	38	0 109	0 0545	0 020	1122
9	0 170	0 150	0 040	235 2	39	0 150	0 109	0 020	438 5
10	0 170	0 150	0 020	246 1	40	0 0235	0 000	0 020	1185
11	0 170	0 150	0 015	258 7	41	0 0235	0 000	0 221	1056
12	0 170	0 150	0 030	274 4	42	0 0235	0 000	0 221	790 3
13	0 150	0 109	0 030	286 6	43	0 0235	0 000	0 221	467 4
14	0 324	0 170	0 040	228 3	44	0 0545	0 0235	0 0567	435 1
15	0 478	0 324	0 040	221 4	45	0 109	0 0545	0 0567	298 6
16	0 324	0 170	0 020	231 1	46	0 150	0 109	0 0567	227 0
17	0 478	0 324	0 020	223 2	47	0 0545	0 0235	0 0567	739 2
18	0 462	0 170	0 020	4219	48	0 109	0 0545	0 0567	467 5
19	0 170	0 150	0 020	4165	49	0 150	0 109	0 0567	275 3
20	0 150	0 109	0 020	4152	50	0 0545	0 0235	0 0567	1000
21	0 109	0 0545	0 020	4134	51	0 109	0 0545	0 0567	674 0
22	0 0545	0 0235	0 020	4129	52	0 150	0 109	0 0567	338 5
23	0 0235	0 000	0 020	4128	53	0 0545	0 0235	0 040	1223
24	0 0235	0 000	0 0375	3686	54	0 109	0 0545	0 040	955 7
25	0 0545	0 0235	0 0375	3664	55	0 150	0 109	0 040	410 3
26	0 109	0 0545	0 0375	3583	56	0 150	0 109	0 0375	1495
27	0 0235	0 000	0 0375	2706	57	0 170	0 150	0 0375	1364
28	0 0545	0 0235	0 0375	2659	58	0 150	0 109	0 0375	3317
29	0 109	0 0545	0 0375	2394	59	0 170	0 150	0 0375	3265
30	0 0235	0 000	0 030	2057	60	0 150	0 109	0 015	370 9

Equivalent length of spring = 0 6833 in

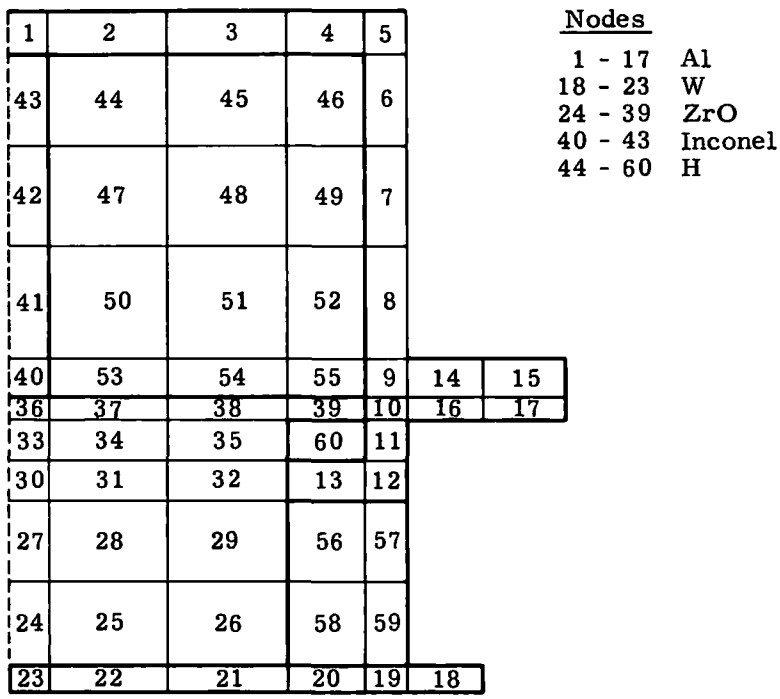


Fig 29 Helical Spring-Plunger Heat Transfer Model

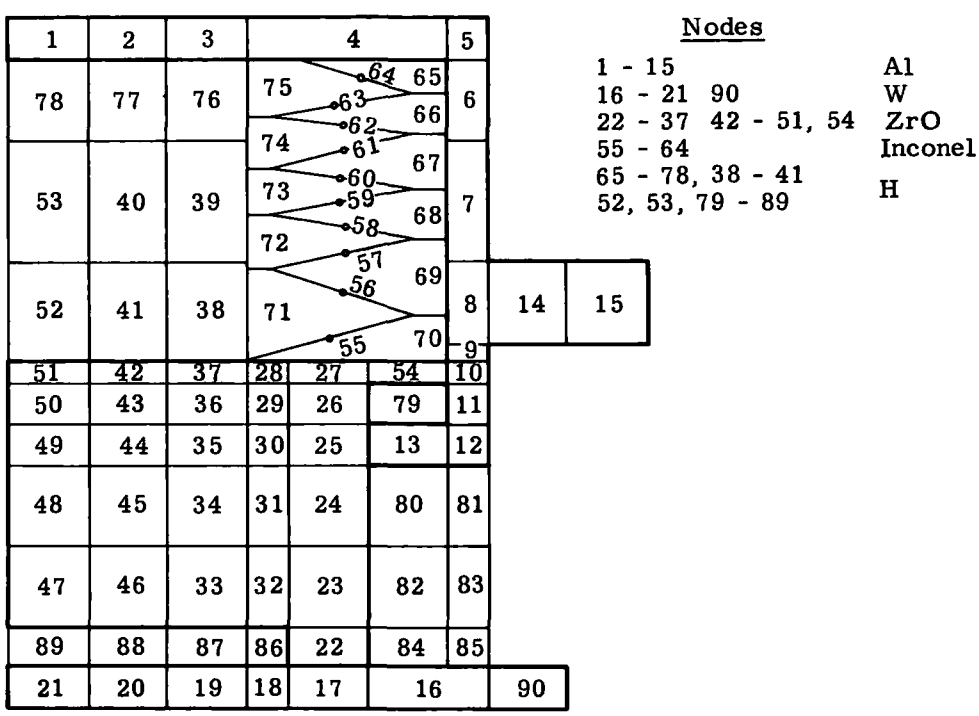


Fig 30 Belleville Spring Plunger, Heat Transfer Model

The assembly was analyzed assuming contact at the highest anticipated support tube temperature which was approximately 4000° F Cooling water at 200° F with a heat transfer coefficient of 5382 Btu/hr-ft^2-°F removed the heat from the assembly The heat transfer coefficient between the gas and the tungsten tube was 2920 Btu/hr-ft^2-°F A gap conductance of 1000 Btu/hr-ft^2-°F was assumed between the tungsten tube and the zirconium oxide An infinite gap conductance was assumed at other intra-assembly contacts (spring-zirconia, spring-aluminum, zirconia-aluminum) The heat generated in the material was 20 watts/gm for all materials Material properties used are as listed in Appendix A

The heat loss from each assembly, located at the bottom of the fuel elements, is 0 179 Btu/sec. The maximum spring and aluminum temperatures are 1185° and 287° F, respectively

A Belleville spring-plunger similar to the helical spring support was analyzed, and the thermal model is shown in Fig 30 The spring consists of a stack of 10 Belleville washers Heat generation rates, heat transfer coefficients, gap conductances and materials used were the same as those used for the helical spring-plunger analysis previously described

Nodal dimensions and temperatures are listed in Table 10 The maximum spring and aluminum temperatures are 775° and 333° F, respectively The total heat loss from the assembly, located below the heat stage, is 0 172 Btu/sec

A third type of spring-plunger support was analyzed to determine the temperature distribution A tapered helical (conical) spring replaces the constant diameter helix shown in Fig 29 However, since the spring is conical, the heat transfer surface is smaller at the top of the spring than at the bottom Furthermore, the assembly is shorter than that shown in Fig 29 The heat transfer model analyzed is shown in Fig 31 The conical spring was replaced by a single column (Nodes 45 to 48) All constants in the calculation were the same as those used in the helical spring and Belleville spring models The dimensions that were used and the resulting temperatures are listed in Table 11 The maximum spring and aluminum temperatures are 919° and 382° F, respectively, and the heat loss is 0 281 Btu/sec

TABLE 10

Belleville Spring Plunger Nodal Dimensions and Temperatures

Node	r_2 (in)	r_1 (in)	h (in.)	T (°F)	Node	r_2 (in)	r_1 (in)	h (in.)	T (°F)
1	0 0333	0 0000	0 030	208 2	45	0 0333	0 0000	0 020	3410
2	0 0667	0 0333	0 030	208 5	46	0 0333	0 0000	0 020	3161
3	0 1000	0 0667	0 030	209 1	47	0 0333	0 0000	0 030	2843
4	0 2345	0 1000	0 030	211 1	48	0 0333	0 0000	0 015	2576
5	0 2645	0 2345	0 030	204 7	49	0 0333	0 0000	0 020	2384
6	0 2645	0 2345	0 0075	201 1	50	0 0333	0 0000	0 100	1326
7	0 2645	0 2345	0 0875	205 7	51	0 0333	0 0000	0 100	659 3
8	0 2645	0 2345	0 060	255 6	52	0 2345	0 1875	0 020	608 3
9	0 2645	0 2345	0 020	279 7	53*	0 1688	0 0000	0 025	774 7
10	0 2645	0 2345	0 015	292 6	54*	0 1688	0 0000	0 025	722 9
11	0 2645	0 2345	0 030	309 0	55*	0 1688	0 0000	0 025	671 2
12	0 2345	0 1875	0 030	332 8	56*	0 1688	0 0000	0 025	617 7
13	0 3712	0 2645	0 060	248 4	57*	0 1688	0 0000	0 025	562 3
14	0 4779	0 3712	0 060	240 1	58*	0 1688	0 0000	0 025	506 0
15	0 2645	0 1875	0 020	3966	59*	0 1688	0 0000	0 025	448 8
16	0 1875	0 1250	0 020	3972	60*	0 1688	0 0000	0 025	388 7
17	0 1250	0 1000	0 020	3981	61*	0 1688	0 0000	0 025	324 1
18	0 1000	0 0667	0 020	3984	62*	0 1688	0 0000	0 025	254 5
19	0 0667	0 0333	0 020	3987	63	0 2345	0 1673	0 0081	221 2
20	0 0333	0 0000	0 020	3989	64	0 2345	0 1673	0 0081	353 3
21	0 1875	0 1250	0 020	3548	65	0 2345	0 1673	0 0081	419 3
22	0 1875	0 1250	0 020	2991	66	0 2345	0 1673	0 0081	507 7
23	0 1875	0 1250	0 020	2426	67	0 2345	0 1673	0 0081	588 3
24	0 1875	0 1250	0 030	1755	68	0 2345	0 1673	0 0081	875 7
25	0 1875	0 1250	0 015	1521	69	0 1673	0 1000	0 0081	814 1
26	0 1875	0 1250	0 020	1347	70	0 1673	0 1000	0 0081	728 5
27	0 1250	0 1000	0 020	1266	71	0 1673	0 1000	0 0081	545 9
28	0 1250	0 1000	0 015	1774	72	0 1673	0 1000	0 0081	451 3
29	0 1250	0 1000	0 030	2273	73	0 1673	0 1000	0 0081	289 3
30	0 1250	0 1000	0 020	2780	74	0 1000	0 0667	0 1000	339 2
31	0 1250	0 1000	0 020	3158	75	0 0667	0 0333	0 1000	351 5
32	0 1000	0 0667	0 020	3264	76	0 0333	0 0000	0 1000	358 6
33	0 1000	0 0667	0 020	2950	77	0 2345	0 1875	0 015	457 4
34	0 1000	0 0667	0 030	2542	78	0 2345	0 1875	0 020	1049
35	0 1000	0 0667	0 015	2206	79	0 2645	0 2345	0 020	941 6
36	0 1000	0 0667	0 020	1880	80	0 2345	0 1875	0 020	2274
37	0 1000	0 0667	0 100	1110	81	0 2645	0 2345	0 020	2170
38	0 0667	0 0333	0 100	637 2	82	0 2345	0 1875	0 020	3404
39	0 0667	0 0333	0 100	1250	83	0 2645	0 2345	0 020	3367
40	0 0667	0 0333	0 020	2259	84	0 1250	0 1000	0 020	3643
41	0 0667	0 0333	0 015	2456	85	0 1000	0 0667	0 020	3691
42	0 0667	0 0333	0 030	2741	86	0 0667	0 0333	0 020	3730
43	0 0667	0 0333	0 020	3087	87	0 0333	0 0000	0 020	3752
44	0 0667	0 0333	0 020	3358	88	0 4622	0 2645	0 020	3977

* Dimensions for 53 through 62 are mean radii and the length volume for each node is 0 000334 in ^{3} Washer thickness is 0 0126 inch

TABLE 11

Conical Spring Plunger Nodal Dimensions and Temperatures

Node	r_2 (in)	r_1 (in)	h (in)	T (°F)	Node	r_2 (in)	r_1 (in)	h (in)	T (°F)
1	0 055	0 000	0 030	219 9	39	0 310	0 281	0 030	576 1
2	0 110	0 055	0 030	219 7	40	0 281	0 220	0 030	1442
3	0 165	0 110	0 030	219 6	41	0 220	0 165	0 030	2121
4	0 220	0 165	0 030	219 8	42	0 165	0 110	0 030	2498
5	0 281	0 220	0 030	221 4	43	0 110	0 055	0 030	2696
6	0 310	0 281	0 030	224 4	44	0 055	0 000	0 030	2786
7	0 340	0 310	0 030	228 0	45*	0 030	0 000	0 2906	919 4
8	0 340	0 310	0 0205	236 5	46	0 030	0 000	0 2906	812 7
9	0 340	0 310	0 0205	245 2	47	0 030	0 000	0 2906	700 1
10	0 340	0 310	0 0205	256 1	48*	0 030	0 000	0 2906	585 2
11	0 340	0 310	0 0205	269 8	49	0 310	0 281	0 0205	292 3
12	0 340	0 310	0 030	290 8	50	0 310	0 281	0 0205	364 5
13	0 340	0 310	0 030	352 6	51	0 310	0 281	0 0205	420 9
14	0 340	0 310	0 030	369 2	52	0 310	0 281	0 0205	484 9
15	0 310	0 281	0 030	381 7	53	0 220	0 165	0 0205	1690
16	0 809	0 680	0 030	232 2	54	0 165	0 110	0 0205	2007
17	0 830	0 809	0 030	226 8	55	0 110	0 055	0 0205	2176
18	0 809	0 680	0 030	416 6	56	0 055	0 000	0 0205	2253
19	0 830	0 809	0 030	423 6	57	0 055	0 000	0 0205	1658
20	0 055	0 000	0 030	4006	58	0 110	0 055	0 0205	1600
21	0 110	0 055	0 030	4004	59	0 165	0 110	0 0205	1475
22	0 165	0 110	0 030	3999	60	0 220	0 165	0 0205	1252
23	0 220	0 165	0 030	3992	61	0 220	0 165	0 0205	841 9
24	0 281	0 220	0 030	3983	62	0 165	0 110	0 0205	965 1
25	0 310	0 281	0 030	3980	63	0 110	0 055	0 0205	1041
26	0 340	0 310	0 030	3978	64	0 055	0 000	0 0205	1077
27	0 809	0 680	0 030	3973	65	0 055	0 000	0 0205	505 2
28	0 281	0 220	0 090	3619	66	0 110	0 055	0 0205	493 0
29	0 281	0 220	0 030	2010	67	0 165	0 110	0 0205	467 8
30	0 220	0 165	0 030	2875	68	0 220	0 165	0 0205	435 3
31	0 165	0 110	0 030	3221	69	0 055	0 000	0 030	3782
32	0 110	0 055	0 030	3387	70	0 110	0 055	0 030	3750
33	0 055	0 000	0 030	3460	71	0 165	0 110	0 030	3679
34	0 055	0 000	0 030	3161	72	0 220	0 165	0 030	3560
35	0 110	0 055	0 030	3073	73	0 310	0 281	0 090	2654
36	0 165	0 110	0 030	2875	74	0 340	0 310	0 090	2375
37	0 220	0 165	0 030	2486	75	0 310	0 281	0 030	613 1
38	0 281	0 220	0 030	1722					

* Contact area at top = 0 01508 in ^{2} contact area at bottom = 0 03142 in ^{2}

Equivalent spring length = 1 162 in

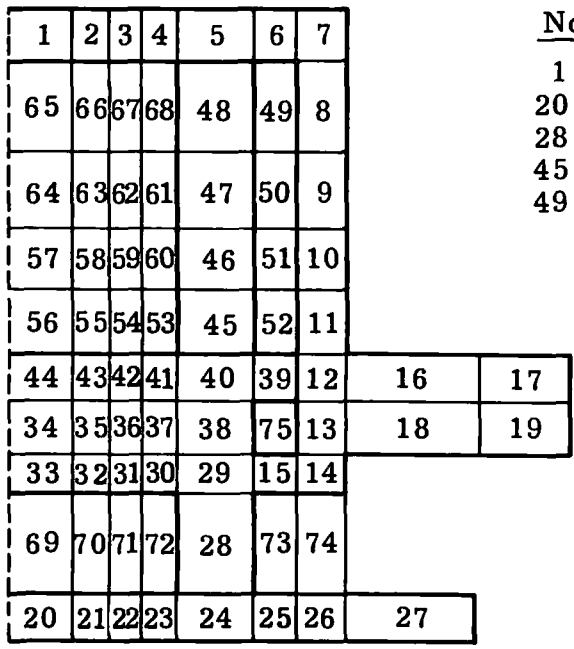


Fig 31 Conical Spring Plunger, Heat Transfer Model

b Spring design and stress evaluation

Helical and Belleville springs have been evaluated Both were tentatively found to be structurally adequate for use in a fuel assembly support system Sizing of these springs was based on using a superalloy material and limiting the maximum stress (in bottomed position) due to dynamic loading to 70,000 psi for helical springs and 200,000 psi for Belleville springs It is noted that a seemingly high stress level (200,000 psi) was used for design of the Belleville springs Belleville springs made from ordinary steel are often designed to stress levels of 300,000 psi and higher and are not considered overstressed due to the very local nature of the highly stressed region.

For a mounting system utilizing compression springs symmetrically placed around the support tube circumference, a static spring preload is recommended The most efficient preload is one half of the maximum anticipated dynamic load Some advantages of a preload equal to or greater than the optimum are

(1) Complete unloading of any spring in the system is avoided

(2) The dynamic deflection of the preloaded spring will be one-half that of an identical spring having zero preload

(3) The effective spring constant of the preloaded system will be double that of an identical system having zero preload

Assuming that a preload equal to one-half of the maximum dynamic load is utilized, the steady-state spring stress will be one-half the dynamic stress or approximately 35,000 psi for helical springs and 100,000 psi for Belleville springs

c Spring design curves

Since the spring design criteria such as allowable deflection, bottoming load, required spring rate, number of springs, etc , are subject to change, a general study was performed and parametric curves generated for design use Dimensional ranges are chosen to include springs which will fit in the available space as shown on Fig 6

Plots for the helical coil springs are shown as Figs 32 and 33 These curves show spring constant, k, deflection to bottom, Δ, spring plus button extension length, L, and wire diameter, d, as a function of spring pitch diameter, D_m, for various values of load-to-bottom, P, in a range from 5 to 40 pounds These curves reflect the following assumptions

E = Young's modulus = $21(10)^6$ psi

S_b = stress in bottomed position = 70,000 psi

N_a = number of active coils = 1

N_{tot} = number of total coils = 3

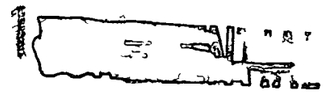
Curves for the Belleville springs are shown as Fig 34 This plot shows deflection to bottom, Δ, outside diameter, OD, and free standing height, H, as a function of the inside height-to-thickness, h/t, ratio for various values of load-to-bottom, P, in a range from 10 to 100 pounds

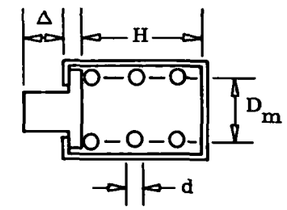
These curves reflect the following assumptions

Outside-to-inside diameter ratio = OD/ID = 2

S_b = maximum stress in bottomed position = 200,000 psi

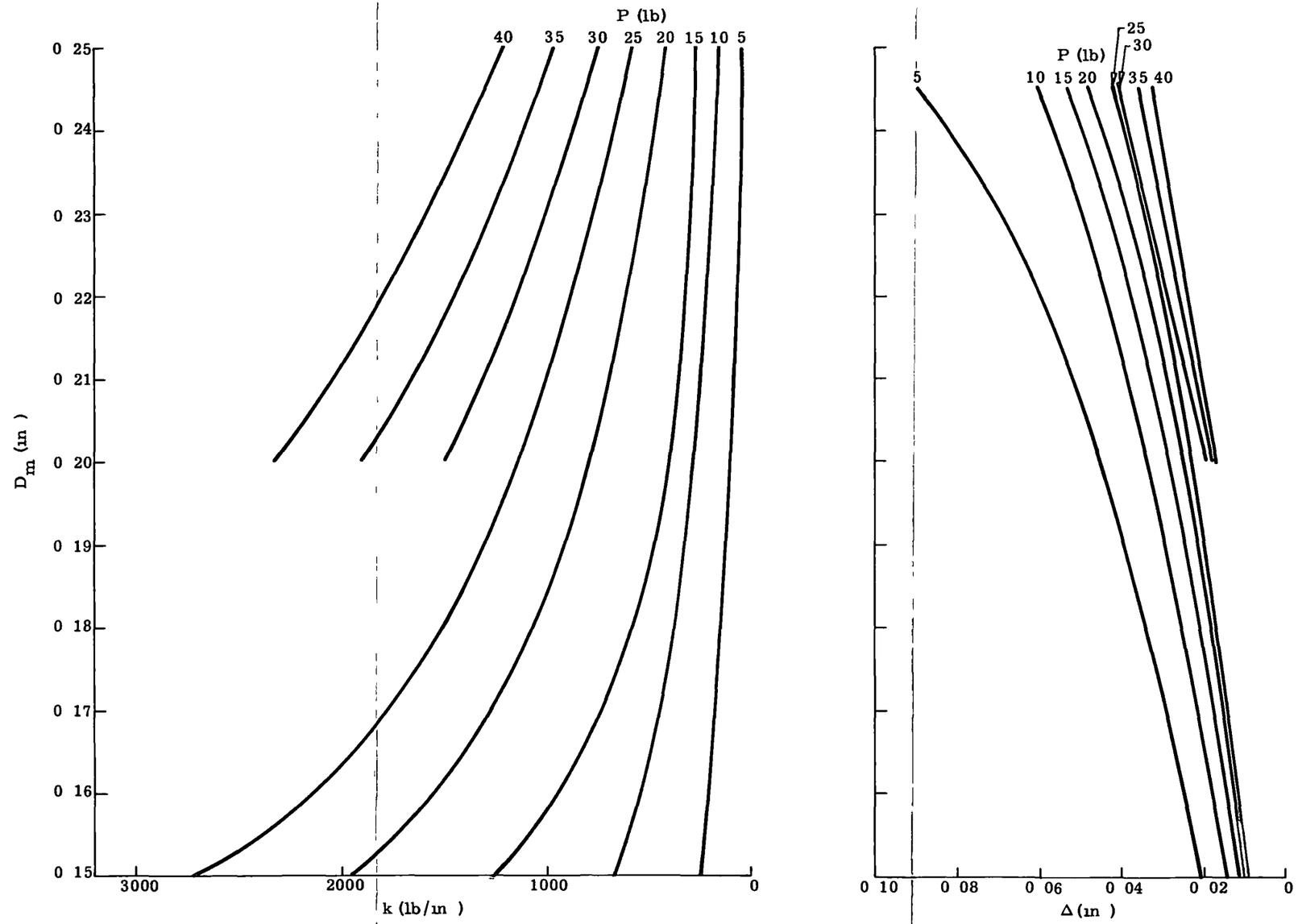
E = Young's modulus = $30(10)^6$ psi





L = H + Δ
P = load to bottom
Δ = deflection from free standing height to solid height
d = wire diameter
E = Young's modulus = $21\ (10)^6$ psi
S = maximum stress at solid height = 70,000 psi

One active coil
Three coils total



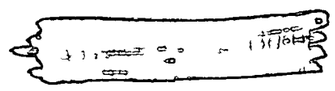


Fig 32 Helical Spring Rate and Deflection as a Function of Pitch Diameter, Parametric in Bottoming Load

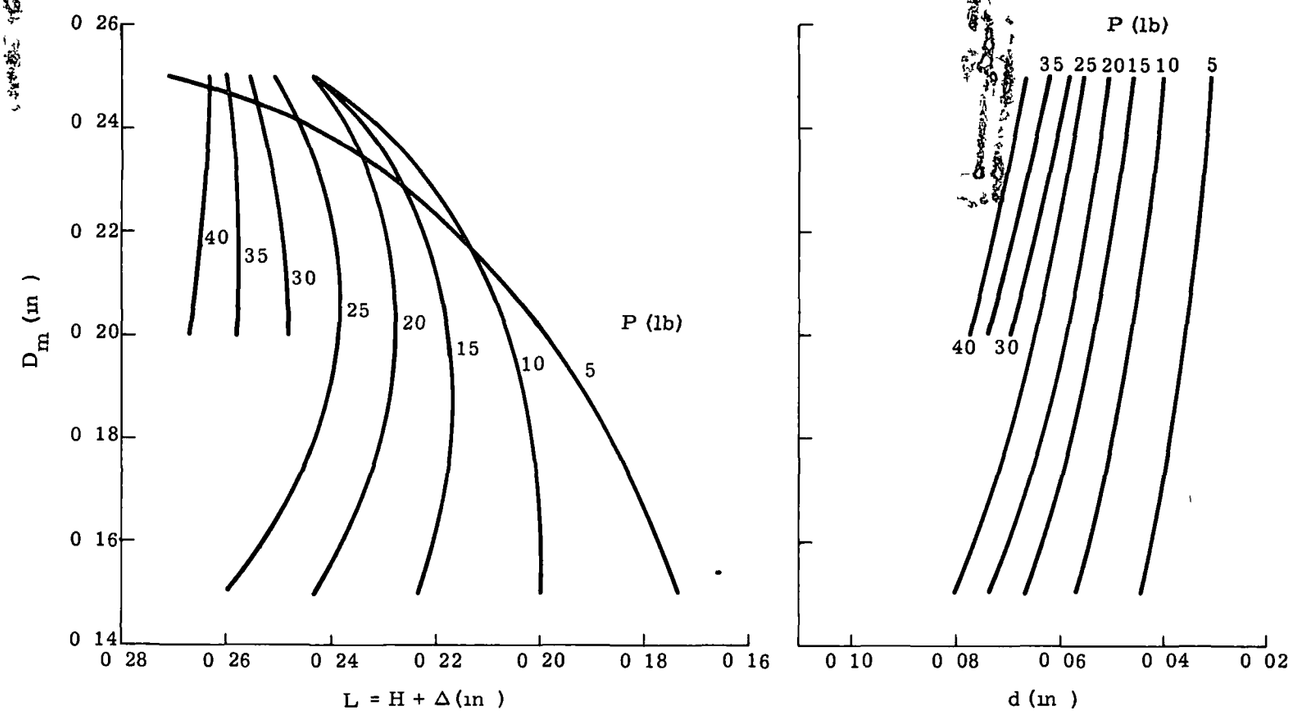


Fig 33 Helical Spring Free Length Plus Deflection to Bottom and Wire Diameter as a Function of Pitch Diameter, Parametric in Bottoming Load

NASA CR-72024
MND-3271

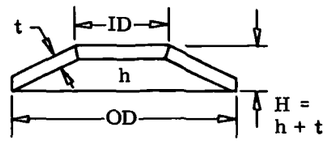
Constant values

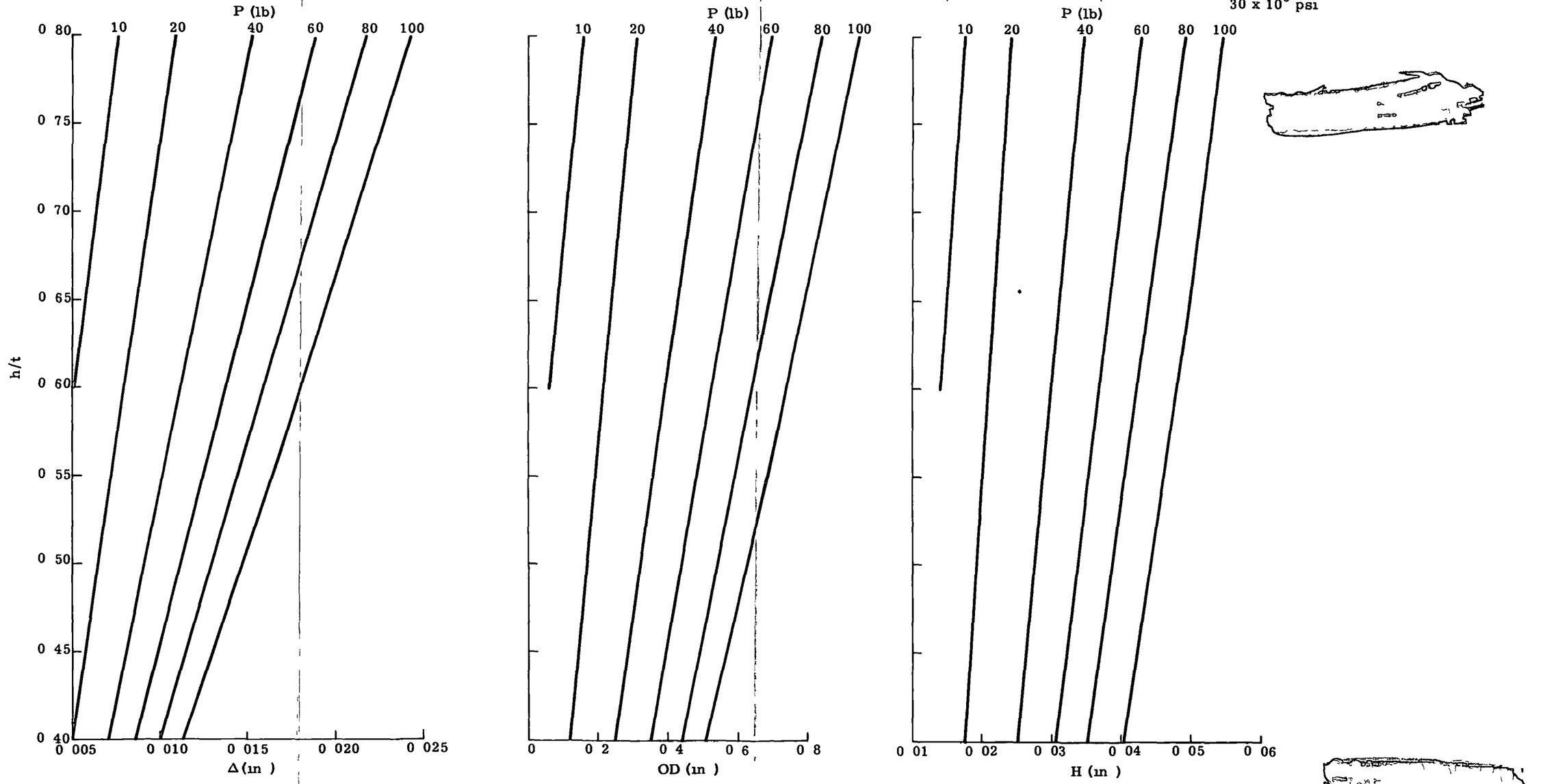
$\frac{OD}{ID} = 2$

S_b = maximum stress in bottomed position = 200,000 psi

Δ = h in bottomed position

E = Young's modulus = 30×10^6 psi





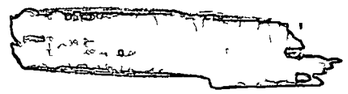


Fig 34 Belleville Spring Characteristics as a Function of h/t Ratio, Parametric in Bottoming Load

Additional spring designs considered were

Tapered helical A tapered helical spring has been considered This configuration has the advantage of a small space requirement in the compression direction because solid height is equal to one wire diameter A disadvantage, in comparison with a mechanically equivalent ordinary helical spring, is that the tapered spring requires a larger diameter on one end This may prove difficult to install in the small space between the support tube and the aluminum tube

Leaf spring supports were considered For analysis these springs were considered as beams fixed at one end (to simulate a brazed connection to the support tube), simply supported at the other end and having a central concentrated load Due to spring contact with the support tube, the springs may be exposed to temperatures well above 2500° F It was found that the structural properties of recrystallized refractories at temperatures above 2000° F are inadequate to provide required spring strength Thus, the leaf spring is considered applicable for use only in locations where the tube temperature is equal to or less than 2000° F This temperature limit is imposed so that refractories in the stress relieved condition may be used

Some additional relaxation data, as presented in Ref 11, p 73, for temperature in excess of 1000° F are presented in Table 12

TABLE 12

Relaxation at Temperatures Above 1000° F

		Heat Treatment			Percent Relaxation at					
					1100 F		1200° F		1300 F	
Alloy	Wire Temper	Temperature (°F)	Time (hr)	Stress (1000 psi)	1 Hour	100 Hours	1 Hour	100 Hours	1 Hour	100 Hours
Inconel	15%	1800	1	60	0 4	1 7	1 5	12 3	--	
Alloy 718		1325	8	50	--	-	1 0	9 7	--	
Inconel	Spring	2100	2	60	2 3	12 0	-	--	-	--
Alloy		1500	24	50	0 6	1 8	-	--		--
X-750		1300	20	40	-	--	0 8	4 1	-	-
				30	--	--	0 8	3 9	1 8	8 0
				20	--	--	--	--	3 8	8 0

Spring materials data were considered and will be discussed briefly

At elevated temperatures, springs under high load and stress are subject to plastic creep and corresponding relaxation of initial load

Since the support springs used will be at elevated temperatures (about 600° to 1000° F) the load relaxation characteristics of these springs must be evaluated, based on the steady-state stress produced by the preload

Some relaxation data for helical compression springs at elevated temperature for various materials are presented in Figs. 35 through 37 Figures 35 and 36 show that at a temperature of 1000° F and stress of 80,000 psi, a relaxation in 20 hours for the materials Rene 41 and A-286 of about 8% will occur Figure 37 is a plot of stress as a function of temperature to produce 5% relaxation in seven days for the Inconel Alloys 718 and 600 This curve shows that at 1000° F, the Alloy 718 may be stressed to 80,000 psi and Alloy 600 to 40,000 psi for a 5% relaxation in seven days.

6 Vibration Analysis

In an elementary study of forced vibration systems, in particular the condition of resonance, the only resisting force preventing extreme amplitude magnification is that of damping There are three major sources of damping existing in the TWMR structural system They are

(1) Viscous damping directly proportional to the lateral velocity, which includes spring damping.

(2) Hydraulic drag by the moderator water surrounding the aluminum pressure tube directly restrains the pressure tube deflection. This damping is directly proportional to the square of the lateral velocity of the tube

(3) Material or hysteresis damping resulting from internal friction of the material's crystallized state, assumed proportional to mass

A displacement or deflection solution of a particular system necessitates the solution of a differential equation of the form

$$Ax + Bx + Cx = F \sin \omega t \qquad (22)$$

where A represents the mass of the system, B is damping, C represents system stiffness and the right side of the equation is the forcing function The only practical solution of this equation entails simulating the structure with a finite number of masses connected by a weightless structure capable of reacting bending and tensile loads, then solving the system by use of a computer Thus, the new form of the equation (in matrix notation) is

$$[A]\, x + [B]\, x + [C]\, x = F \sin \omega t \qquad (23)$$

where

[A] = diagonal mass matrix (lb-sec^2/in)

[B] = damping matrix (lb-sec/in.)

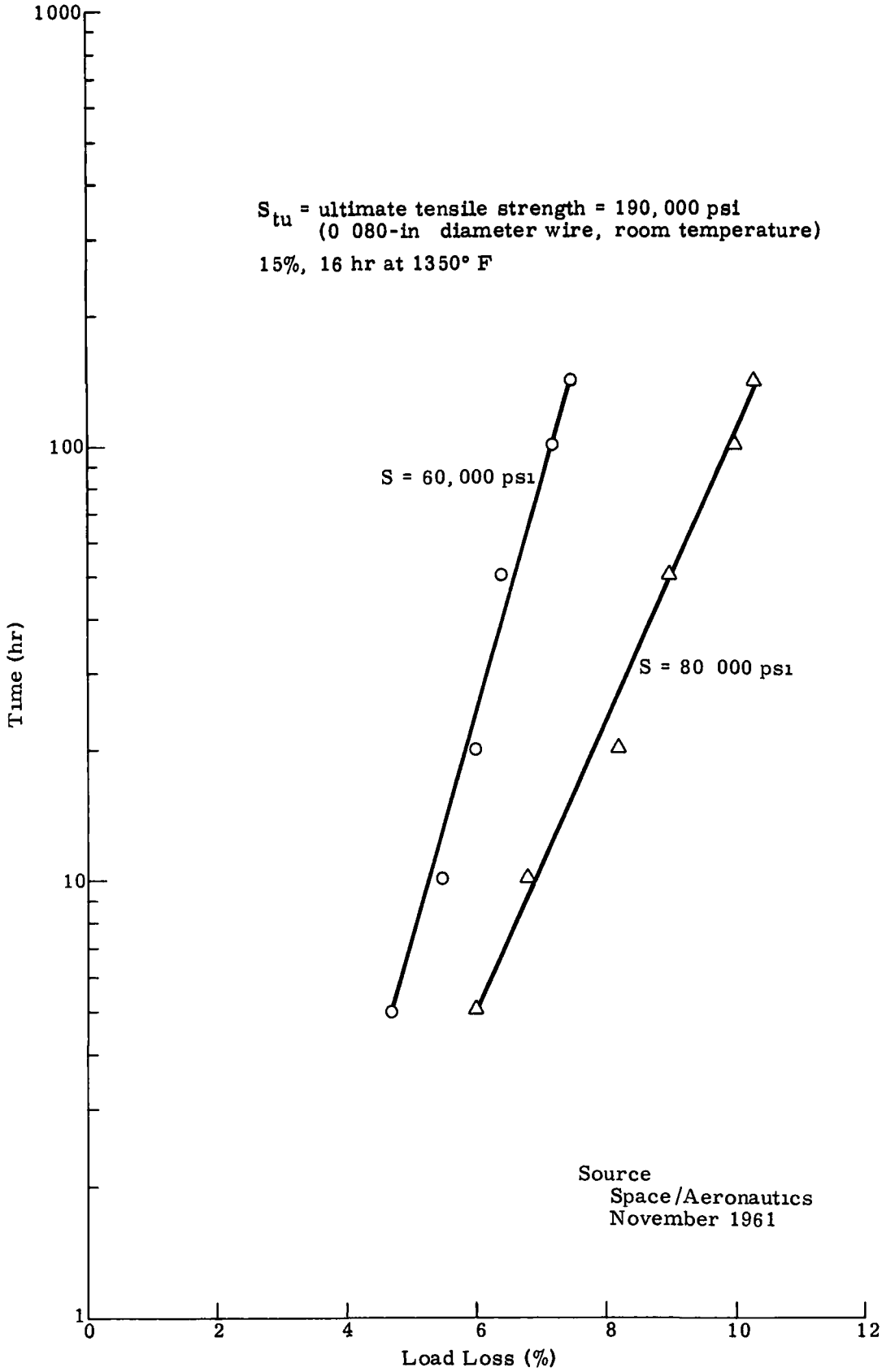


Fig 35 Type A-286 Stainless Steel Helical Spring Load Relaxation as a Function of Time at 1000° F, Parametric in Stress

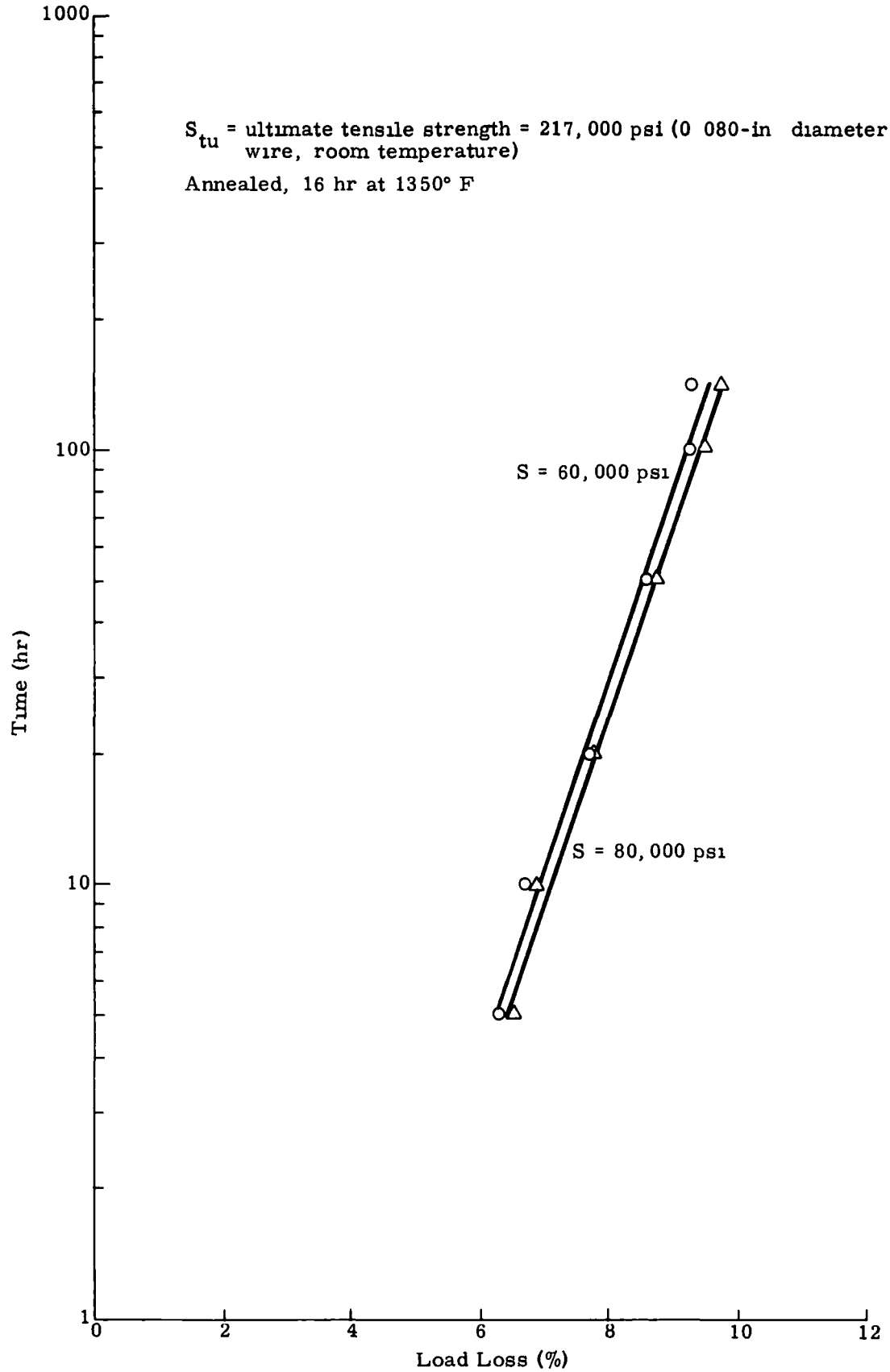
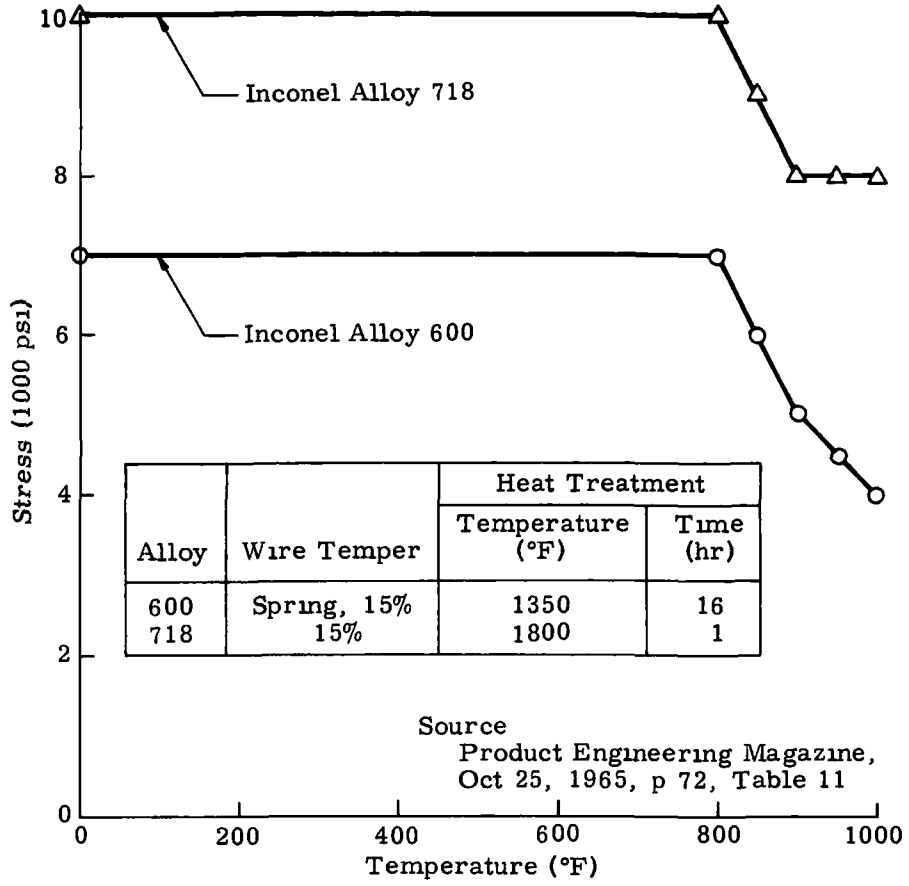


Fig 36 Relaxation of Rene 41 Helical Springs as a Function of Time at 1000° F, Parametric in Stress



Alloy	Wire Temper	Heat Treatment	
		Temperature (°F)	Time (hr)
600	Spring, 15%	1350	16
718	15%	1800	1

Source
Product Engineering Magazine,
Oct 25, 1965, p 72, Table 11

Fig 37 Stress to Produce 5% Relaxation in Seven Days as a Function of Temperature for Inconel Alloys 718 and 600

[C] = stiffness matrix (lb/in)

x = acceleration vector (in /sec^2)

x = velocity vector (in /sec)

x = displacement vector (in)

ω = resonant frequency (rad/sec)

Upon attainment of the displacement solution, the required stesss solution is found by·

$$\{\sigma\} = [s]\ [C]\ \{x\} \tag{24}$$

where

[s] = stresses due to unit loads (psi/lb)

The Martin Company has two computer programs designated UB012 and UB079 for the solution of N second order simultaneous differential equations with M time dependent inputs and R sets of additional equations such as Eq (24) The source of the [s] matrix in Eq (24) will be discussed in a succeeding paragraph The basic difference between the two programs is that the coefficient input for UB012 is restricted to constant coefficients or constant matrix components UB079 has the versatility of utilizing complex or variable coefficients For the TWMR study, UB079 was modified to solve the nonlinear equation.

$$Ax + Bx^2 + Cx + Dx = Ef(t)$$

The choice of program was based solely on the additional generality of coefficient input if it was required

Assume, for the moment, that the three general damping sources may be considered independently For spring damping, only the mass points at each spring location are involved This results in a damping matrix [B] having finite values at a number of discrete points corresponding to the locations of spring reactions with zeros entered elsewhere Either UB012 or UB079 can readily handle these cases However, in the case of water damping, the restoring force is proportional to the velocity squared The result is a set of simultaneous nonlinear equations of the form

$$[A]\ x + [B_1]\ x + [B_2]\ x^2 + [C]\ x = F \sin \omega t \tag{25}$$

where the B_1 matrix represents the linear damping coefficients such as spring and viscous damping, etc , and the matrix, B_2, represents the damping coefficients for the nonlinear terms The B_2 coefficients are obtained from the common fluids parameter

$$B_2 = 1/2 \rho C_D ld \tag{26}$$

where

ρ = density of the medium (water)

C_D = drag coefficient for circular cylinder longitudinal profile

ld = cylinder cross-sectional area based upon length and diameter

The UB079 program is capable of solving nonlinear forms represented by Eq (25)

The final category of damping considered was that designated as material or hysteresis damping In the study of forced lateral vibration of beams, the resulting equations of motion provide an infinite set of velocity coupled equations When the damping coefficient is proportional to the beam mass distribution, i e , $c(x) = \beta \mu(x)$ where $c(x)$ is the distributed damping coefficient, β is a constant and $\mu(x)$ is mass distribution, the orthogonality relationship provides mathematical decoupling of the equations Similarly, when orthogonality principles are applied in a coordinate transformation of the matrix form of the equations used in the Martin programs, the result is a set of one degree of freedom motion equations of the form

$$\ddot{x}_n + \beta \dot{x}_n + \omega_n^2 x_n = \frac{Q_n}{m_n} \text{ (Refs 20 and 21)}$$

The coefficient matrix [B] of Eq (23) becomes a diagonal matrix equal to mass matrix [A] multiplied by a constant, e g , for 5% material damping, [B] = 0 05 [A] For this last case, where the set of N simultaneous equations become mathematically uncoupled, the Martin Codes UB012 or UB079 are not required The analyst may reach a solution to the system by means of independent differential equations and the constant displacement amplification factor, Q, where

$$Q = \frac{1}{2\beta} \tag{27}$$

where $\beta = c/c_c$, the classical damping factor The previous sample was cited as 5% material damping. Therefore, β = 0 05 and

$$Q = \frac{1}{2(0\ 05)} = 10$$

To solve this problem with the uncoupled equations and to determine ω and $[s]$ for Eqs (23) and (24), a structural program entitled "A Digital Program for Static and Dynamic Analysis of Complex Structures" is required This program, more fully described in Appendix B, is subdivided into two major sections designated as UB038 and UB040 These programs are utilized to solve for the natural frequency modes, stresses and deflections of a complex structure as a result of dynamic loading The technique is one of modal synthesis in which the structure of interest is partitioned into shear, tension and bending elements for which compliances are established The final solution is obtained by matrix techniques With the matrix force method, a model of the structure comprised of grid points and primary and redundant elements (including reactions) is specified The elements have the common property that their internal loads can be represented as force resultants at the grid points Equations of equilibrium at each grid point are established between the internal and external forces of the element Elastic properties are established for all elements of the model, and redundant loads are calculated to make internal deformations and deflections compatible The deflections and rotations of the structure under the action of external loads are then computed

The deflections due to unit loads form a matrix of deflection influence coefficients for the structure as constrained against rigid body motions Fictitious constraints are removed and replaced by an equivalent inertia force system This procedure yields deflection and internal load influence matrices for the unconstrained structure which forms the basis of the dynamic analysis

The UB038 portion of the program provides the following output

(1) Internal load influence matrix

(2) Deflection influence matrix

(3) Damped and undamped frequencies

(4) Normalized mode shapes

The UB040 portion utilizes this information and provides for the mass points

(1) Force amplitudes

(2) Deflections

(3) Velocities

(4) Accelerations

(5) Internal loads

(6) Stresses (for each compliance)

This information is presented for each resonant frequency of interest to the user

Under this contract, the dynamic analysis effort was concentrated on two model assemblies The first model, shown in Fig. 38, is the vibration test model constructed and tested at NASA-Lewis The model consists primarily of an aluminum pressure tube and a three-section support tube (stainless steel-molybdenum-tungsten) at ambient temperature The fuel state mass distribution was simulated The model was tested in the lateral vibrational modes and became an excellent source for data comparison between NASA tests and Martin analytical solutions from the computer programs The second model consists of a typical reference design with assumed lateral support system characteristics Detail description and design results will be covered later in this report

Figure 39 illustrates the computer model which is the simulation of the NASA test model This model consists of 18 mass points (pairs at the exit and entrance ends are combined), tension and bending elements representing internal constraints as well as boundary conditions Support springs are located at Stations 22, 28 5 and 35 (longitudinal distance referenced from the upper tube sheet) The system is considered clamped at the entrance end, whereas there is a nominally simple support between the support and pressure tubes at the exit end The actual restraint of the pressure tube at the exit end is somewhere between the extremes of a simple support and a completely clamped support The two implied limits and their relative influence on the system are studied The temperature is assumed ambient as it was for the actual test model Therefore, the elastic modulus is constant for each material involved

In the computer runs associated with the test model, stresses, deflections and frequencies of the system were investigated with changes in.

(1) Spring constant

(2) Spring damping coefficient

(3) Support constraint of aluminum tube at exit end

(4) Material damping

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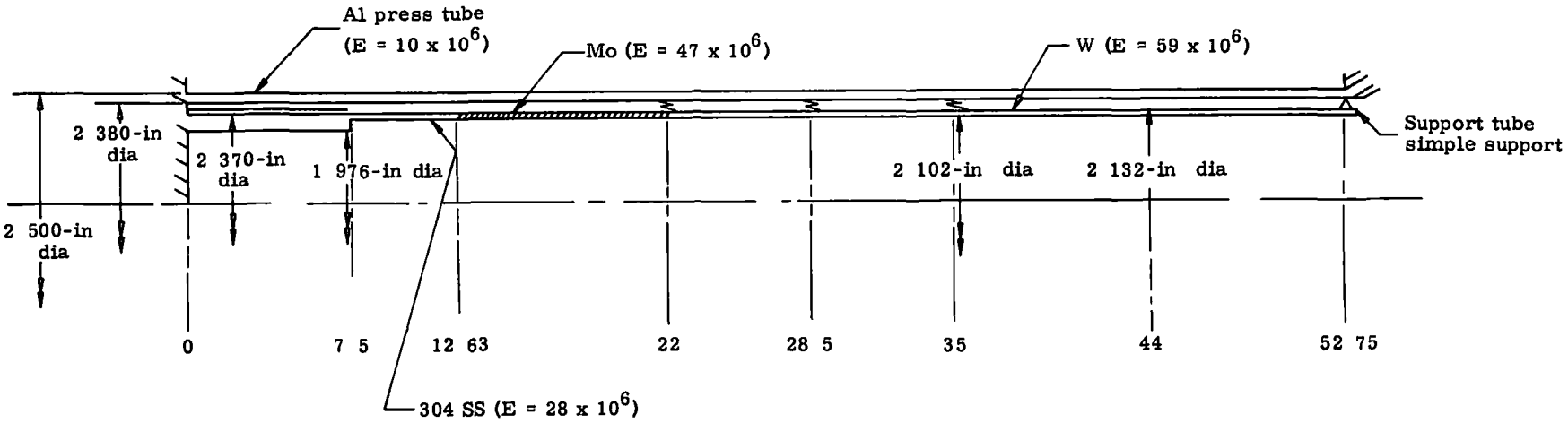

Fig 38 NASA Vibration Test Model

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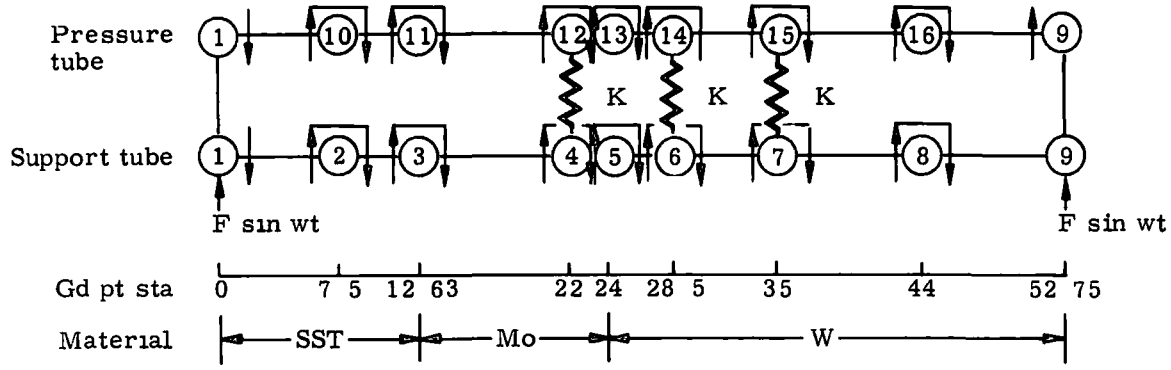


Avg E x 10^{-6}	28 0		28 0		47 0		47 0	59 0		59 0		59 0			59 0		
Avg EI x 10^{-6}	21 82		1 56		2 62		2 62	3 292	3 292		3 292			3 292			
Avg EA x 10^{-6}	37 43		2 80		4 7		4 7	5 9		5 9		5 9			5 9		
Support tube weight*	1000		2 34	4 17			3 35	1 99	3 41		4 80			5 53			1000
Pressure tube weight			0 28	0 33			0 26	0 15	0 25		0 36			0 39			

* Weight includes additional 1000 lb at Grid Points 1 and 9

KEY

- O Mass point
- — Tension element
- Bending element
- Spring

Fig 39 Computer Model of NASA Vibration Test

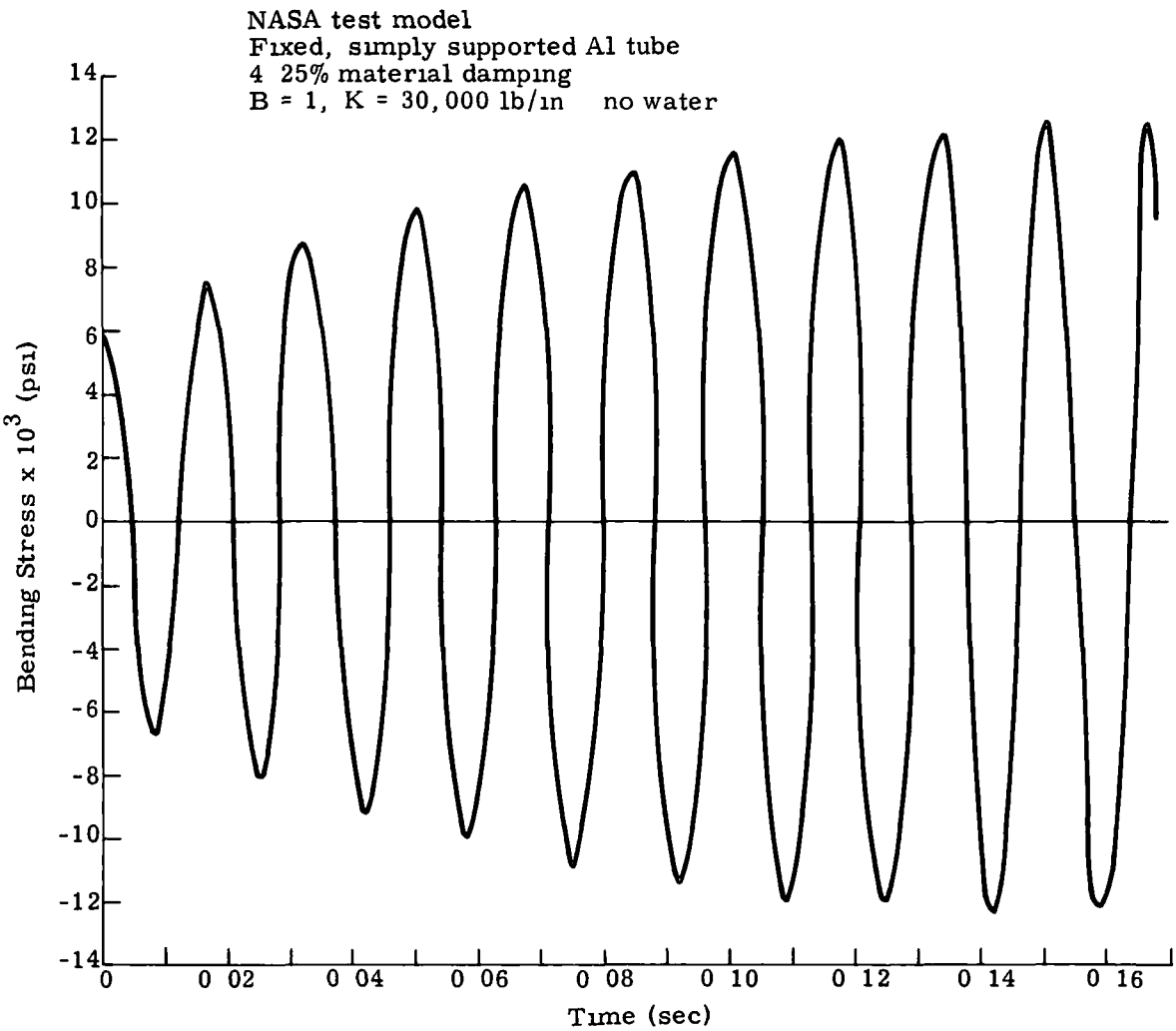


Fig 40 NASA Test Model, Run 6, Support Tube Stress at Station 35 as a Function of Time

In all cases for this model, no water was assumed in the system although the capability exists for evaluation of mass effects and damping effects due to water per UB079 It will be shown that the damping effect of the water is rather insignificant

The general procedure was to first establish the simulated or computer model Large masses of about 1000 pounds were added to the two ends of the system to achieve model displacement stability for the mathematically free-free structure under load A relatively arbitrary force was imposed (in these cases chosen by an amplification factor, Q, of five) and submitted to the 7094 digital computer via the structural programs, UB038 and UB040

The output of interest includes the resonant modes, natural frequency and displacements associated with a Q = 5 The displacements are then applied as the initial conditions for Eq (23) Finally, the program for solution of the simultaneous equations of motion is solved with UB012 This latter program could have been eliminated if only material damping was included Thus, the actual Q could have been computed with Eq (27) and the final stress and deflection results from UB038 and UB040 would be the required system solution This latter case will be described in the discussion of the design model

Computer runs and variable inputs for the NASA vibration model are tabulated in Table 13 The resonant frequency contributing to maximum stresses, a program output, is also included

Figure 40 represents the typical form of results for a given set of spring constants, damping coefficients, etc In particular, this illustrates the maximum bending stress (outer fiber) at Station 35 (35 in from the entrance end) versus time in seconds The design conditions for this run correspond to Run 6 in Table 13 where each of the three springs has a spring constant and spring damping coefficient of 30,000 lb/in and 1 lb-sec/in , respectively Material damping of 4.25% (a typical value developed from NASA-Lewis test data) is included The figure shows the initial condition of stress at t = 0 which is extracted from the UB040 program and becomes an input to the UB012 program The stress function is cyclic and has obtained a maximum value between 0 151 and 0 167 second The resonant frequency is 59 8 cps

Other data for the same model are provided in Fig 41 where bending stress and maximum deflection are plotted versus station

The damping coefficients, geometry and fixity of this model most nearly coincide with the model tested at the NASA-Lewis Research Center The NASA results indicated a resonant frequency of 54 cps and a maximum support tube bending stress of approximately 7000 psi

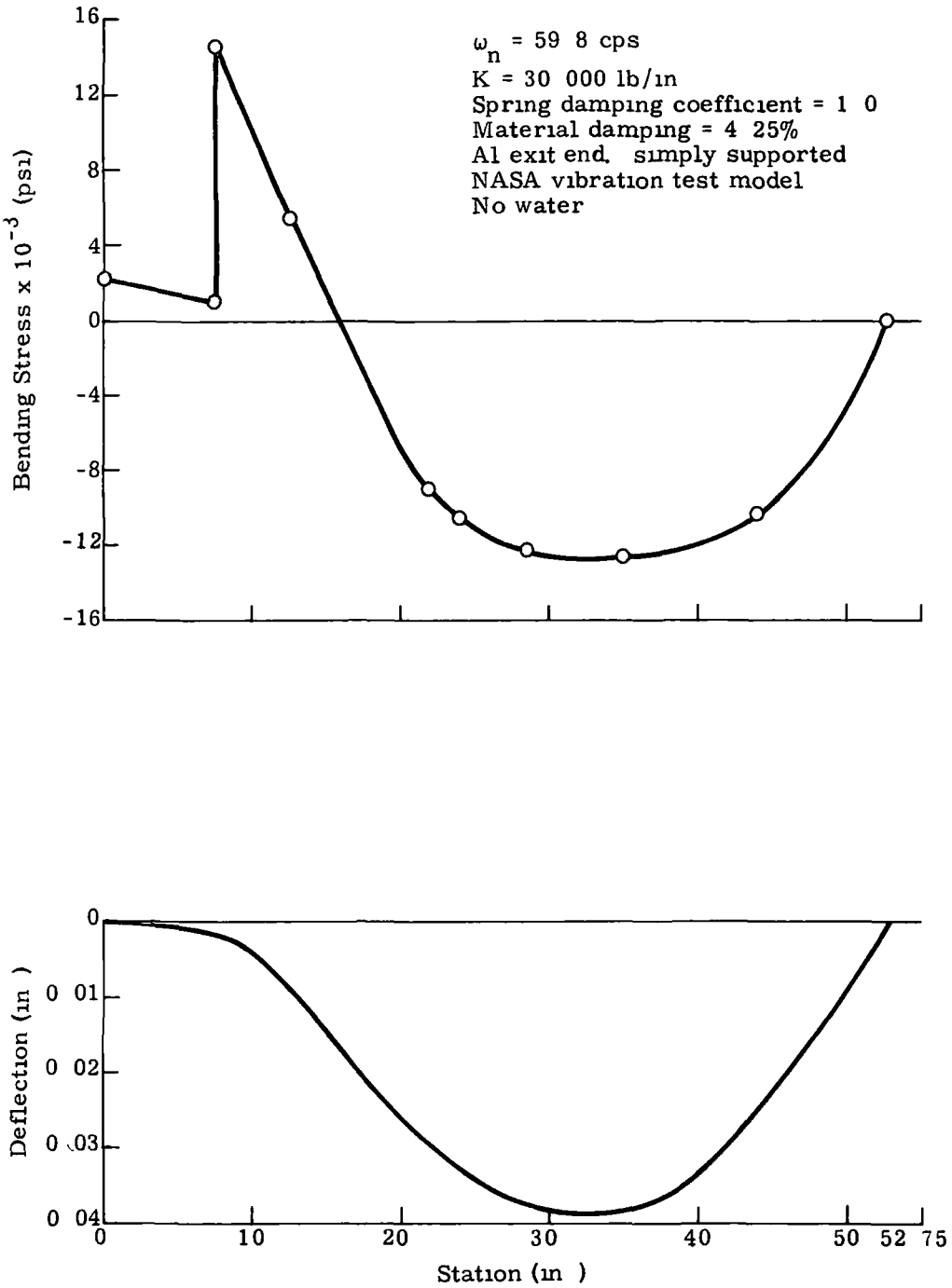


Fig 41 NASA Test Model, Run 6, Stress and Deflection of Support Tube as a Function of Axial Position

TABLE 13

NASA Vibration Model Computer Data

Run	Spring, k (lb/in)	B(1) (lb-sec/in)	BC(2)	ω (cps)	Remarks
1	30,000	6	F-F	73 54	
2	30,000	3	F-F	73 54	
3	30,000	1	F-F	73 54	
4	30,000	0	F-SS	59 80	Initial conditions all 0
5	3,000	1	F-F	64.48	
6	30,000	1	F-SS	59 80	Includes 4.25% material damping

NOTE

(1) B represents spring damping coefficient applied All three springs were given same constant
(2) BC represents boundary conditions of the aluminum support tube where
    (a) F-F implies fixed at both entrance and exit ends
    (b) F-SS implies fixed at entrance end and simply supported at exit end

(Ref 19) Figure 41 indicates a resonant frequency and maximum bending stress of 59 8 cps and 12, 500 psi, respectively Correlation between experimental and calculated frequency and stress is affected by the actual inlet end fixity, the assumed spring and damping coefficients, and, of course, the actual versus the model goemetry

Runs with numerical definitions 1, 2 and 3 were generated primarily to evaluate the influence of the spring damping coefficient on the bending stress magnitude The values examined were 1, 3 and 6 lb-sec/in The results in Fig 42 indicate that stress is not highly affected by the spring damping magnitudes considered Unless springs of much greater damping capacity are utilized, it may be well to neglect spring damping without being overly conservative This range of spring damping coefficients was extracted from NASA-Lewis test data for circumferential convoluted lobe springs of 1-1/2-inch length in both three- and five-mil thicknesses Maximum damping force in pounds was plotted versus maximum velocity in inches per second The two curves were nonlinear in nature, however, the slope limits appeared to be within the approximate values of 0 7 and 8 0 lb-sec/in

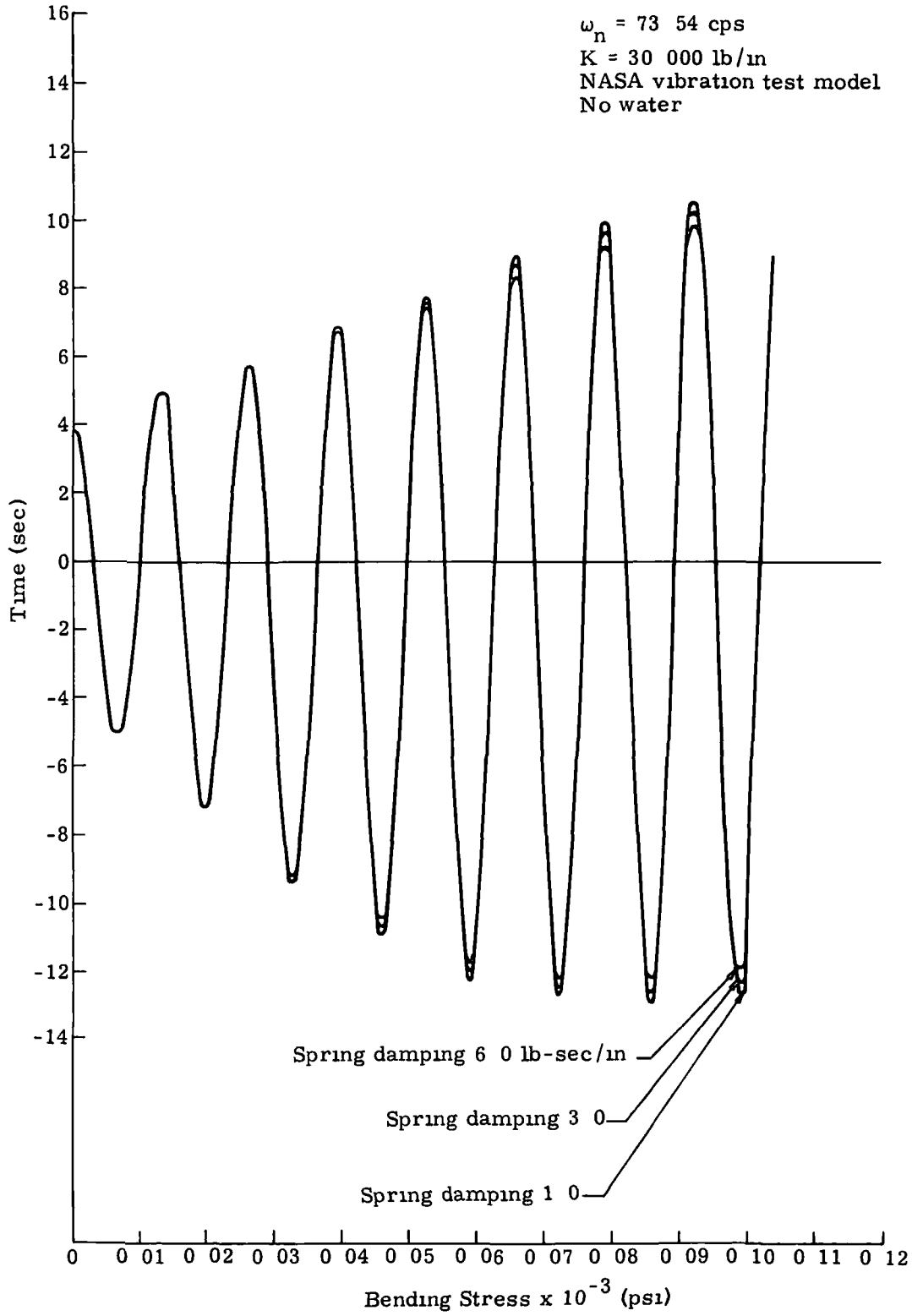


Fig 42 NASA Test Model, Runs 1 to 3, Support Tube Stress at Station 24 as a Function of Time

The case of zero damping with bending stress versus time is shown in Fig 43 for Station 35 of the support tube The divergence of the function corresponds identically with the single-degree-of-freedom theory A more important conclusion regarding the results is that the anticipated behavior of the UB012 computer program was verified Several computer output pages representative of this particular case are included in this report as Appendix D

For illustrative purposes, the maximum bending stress distribution and deflection are shown in Figs 44 and 45 for the model with 6 lb-sec/in spring damping As before, the three springs have identical dynamic spring constants of 30,000 lb/in The distributions, Fig 44 representing the composite support tube and Fig 45 the aluminum pressure tube, are presented at t = 0 072 second or at approximately 5-1/4 periods The resonant frequency was 73 54 cps This case is Run 1 in Table 13

The adjusted deflection curves drawn on the figures are analytical corrections of the actual code output

During the investigation of the lateral vibration characteristics of the composite pressure and support tubes, it was necessary to consider the pressure tube as a free-free beam The resultant code output contained a mathematically induced lateral motion of the exit end support relative to the inlet end To apply the proper system boundary conditions, 1000-pound masses were written in at these two system locations which are in reality fixed in space relative to the surrounding reactor structure However, in some cases the computer solution still resulted in a small amount of system translation as a function of time This output required a simple arithmetic adjustment to measure the true lateral deflection of system points relative to the static configuration centerline Any error in the resulting calculated deflection due to this adjustment is considered negligible

The second system evaluated was that of an operational design as illustrated in Fig 46 The support tube is constructed of three sections, each of which is a different material (columbium, molybdenum and tungsten), brazed at the interfaces, and is subject to an operational temperature distribution from -130° to approximately 3940° F The aluminum pressure tube is assumed fixed at the entrance tube sheet and simply supported at the exit tube sheet Three spring locations were chosen to minimize the number of computer model grid points Spring locations and rates were chosen on the basis of the NASA experimental runs and are tabulated as follows

Spring 1 at Station 24 875 in 26,000 lb/in

Spring 2 at Station 34 34 in 24,000 lb/in

Spring 3 at Station 43 80 in 21,000 lb/in

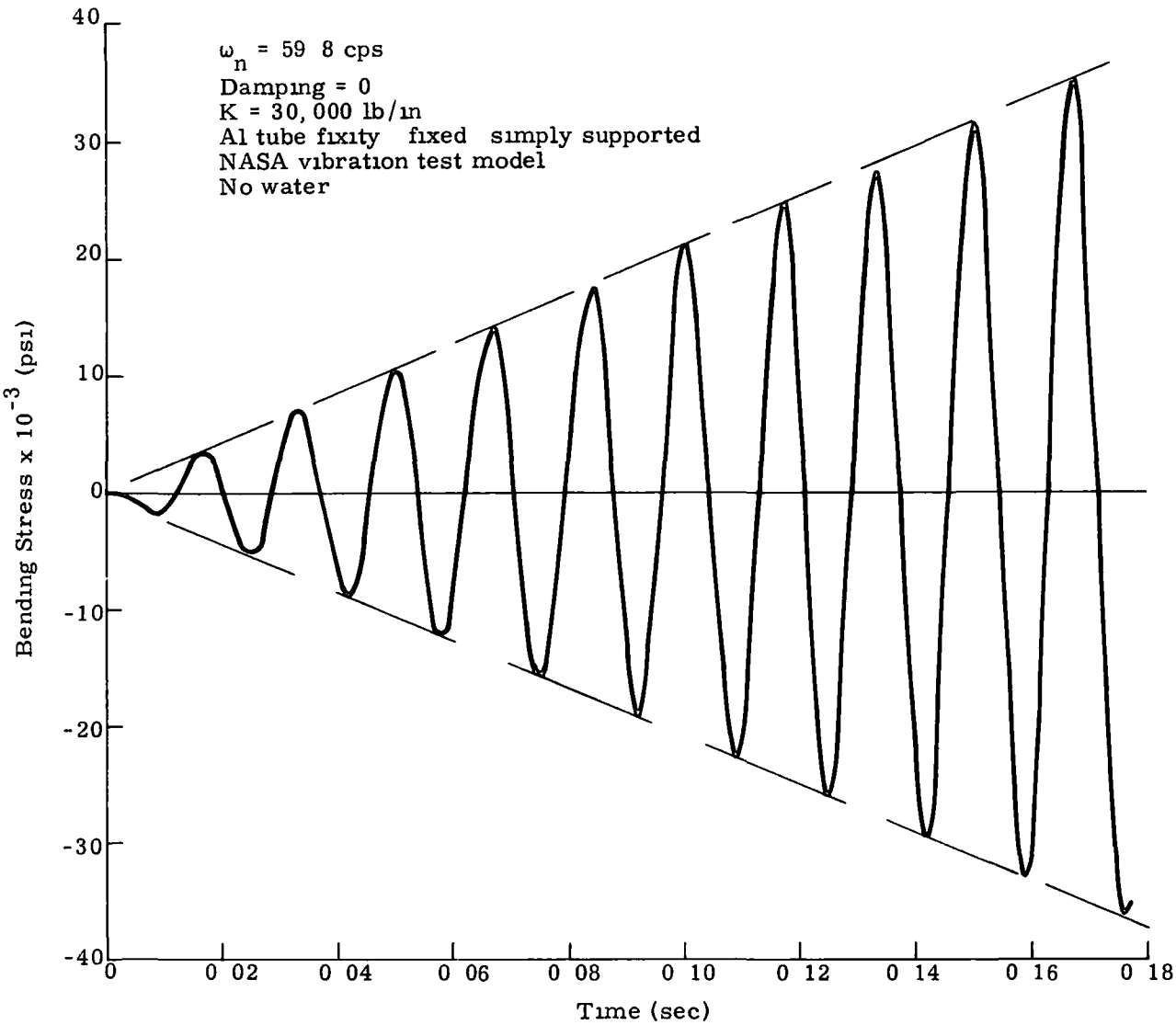


Fig 43 NASA Test Model, Run 4, Stress at Station 35 as a Function of Time

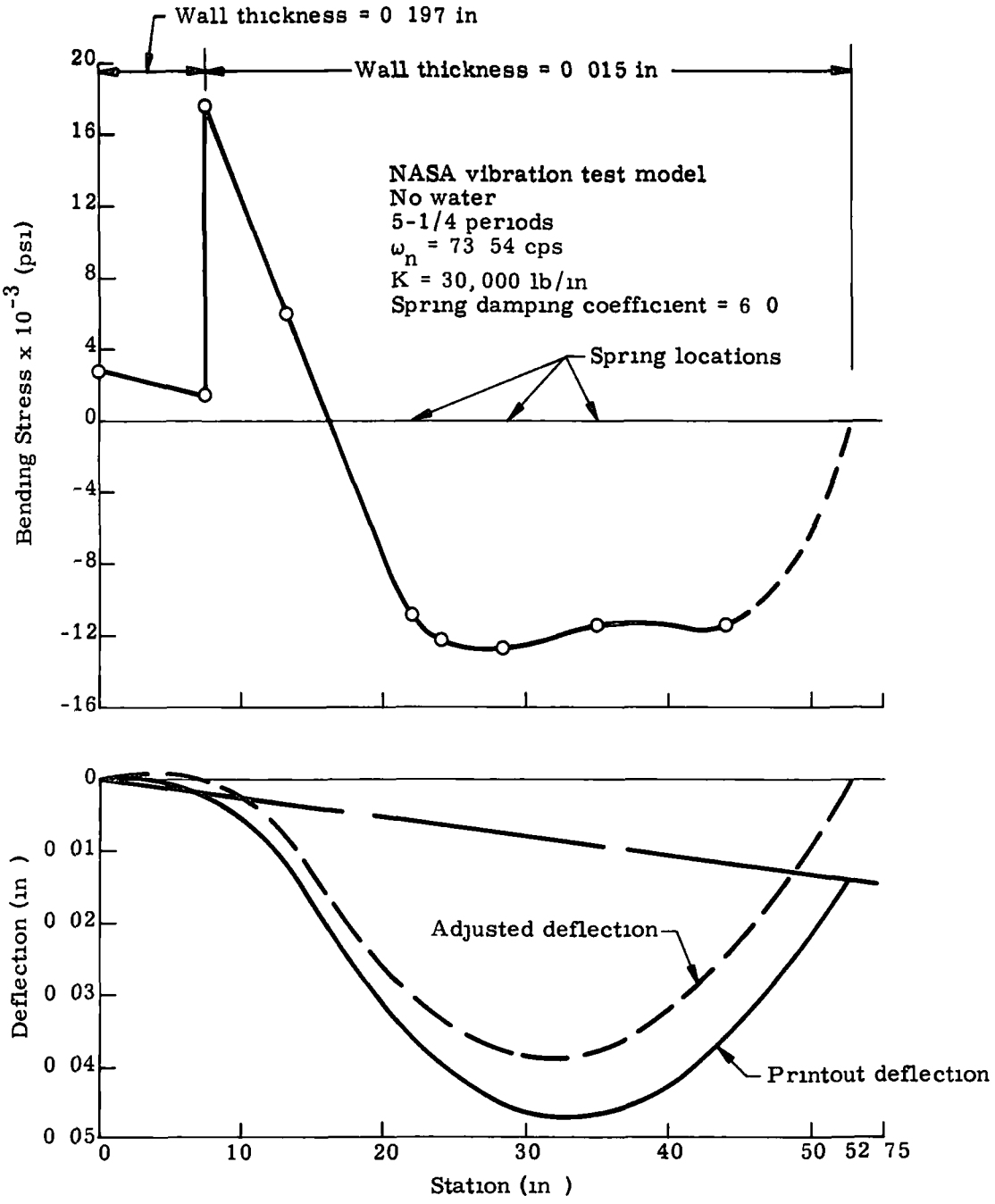


Fig 44 NASA Test Model, Run 1, Stress and Deflection of Support Tube as a Function of Axial Position

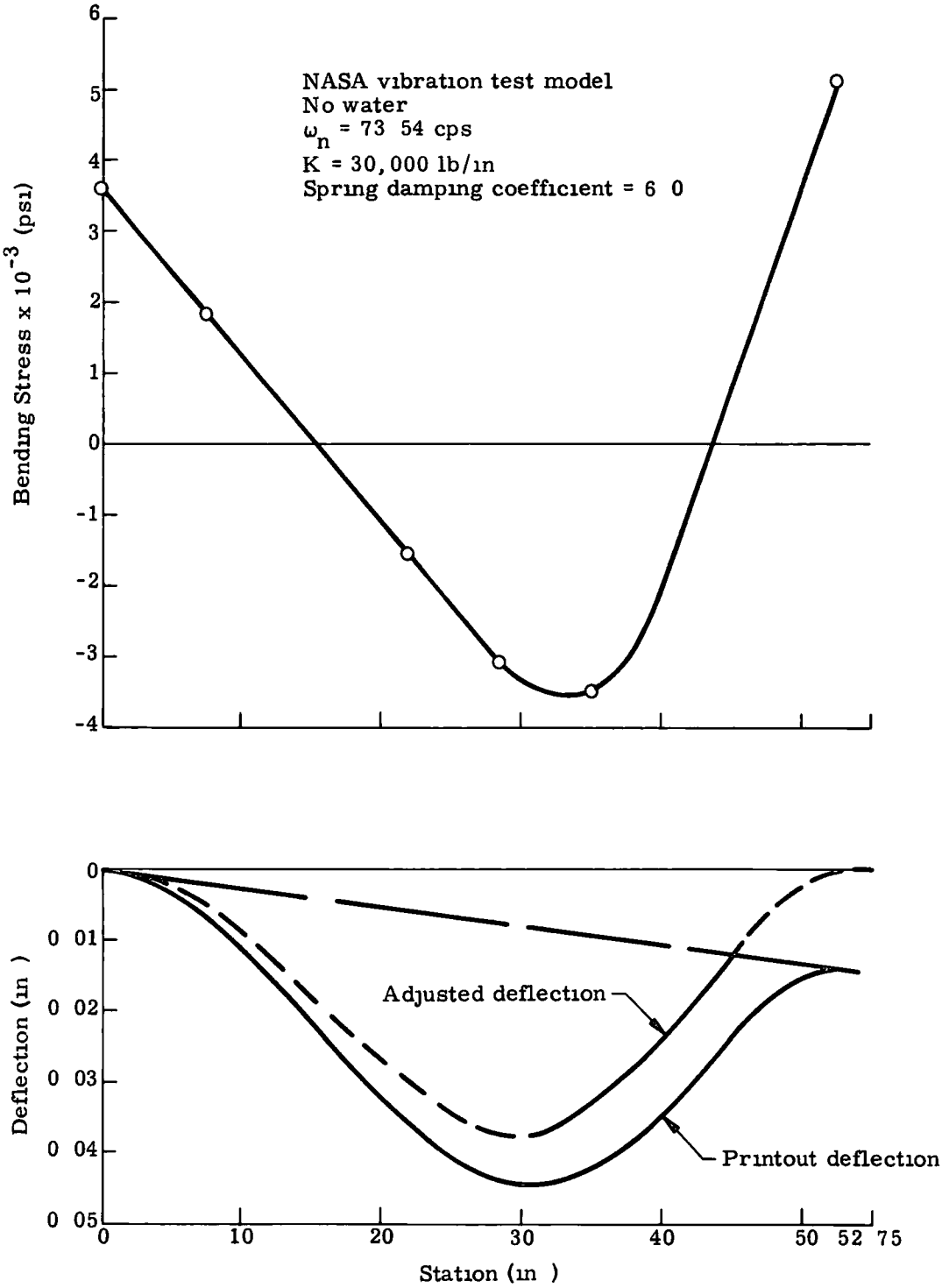
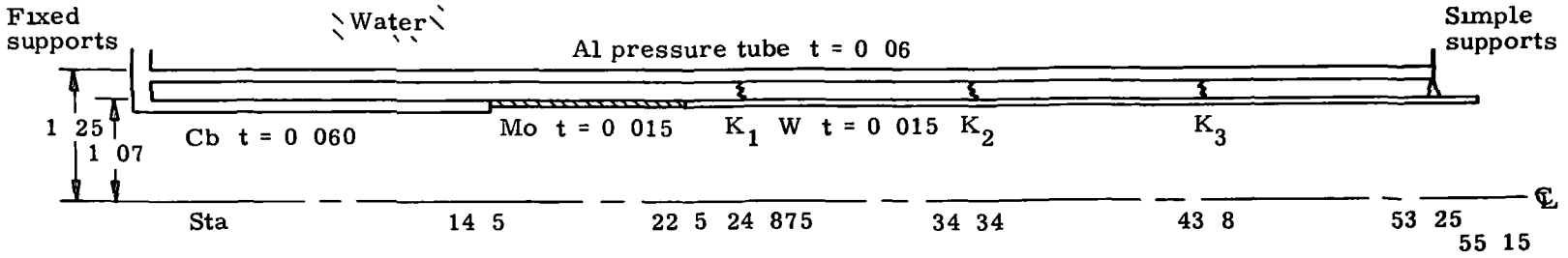


Fig 45 NASA Test Model, Run 1, Stress and Deflection of Pressure Tube as a Function of Axial Position



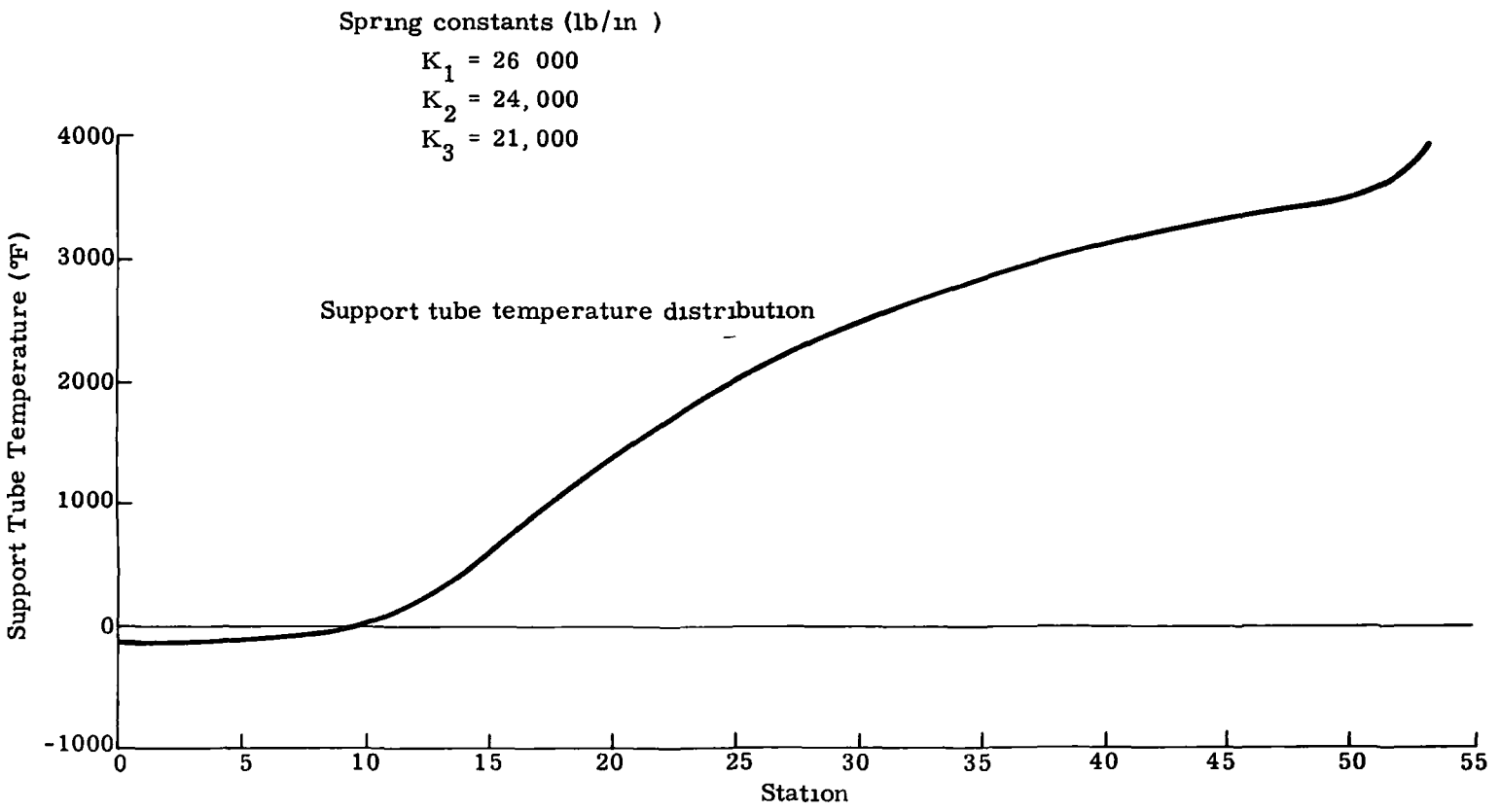


Fig 46 Design Model, Lateral Support System Analysis

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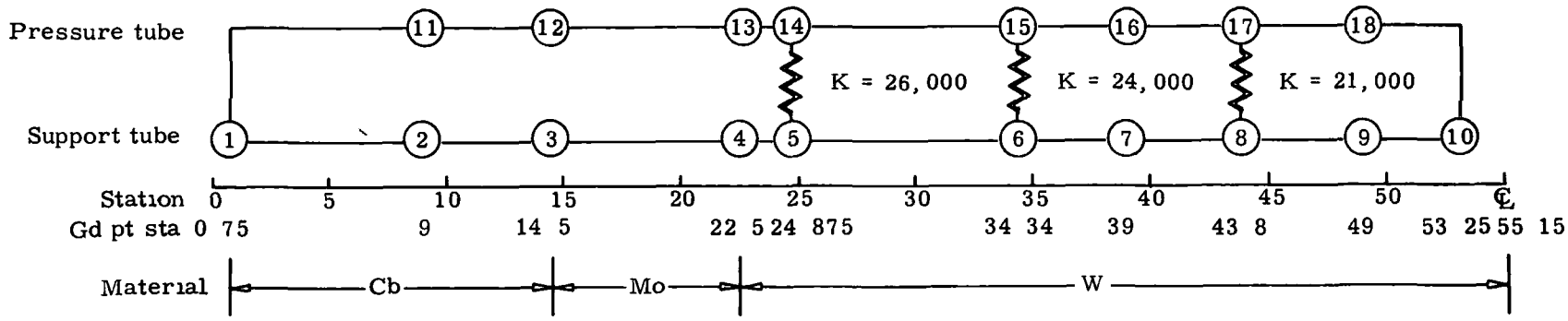
MND-3271



Temp (°F)	+ -138	+ -20	+ 560	+ 1740	+ 2000	+ 2800	+ 3070	+ 3290	+ 3450	+ 3940
Avg temp	-100	190	1190	1875	2460	2960	3200	3380	3570	
Avg E x 10^{-6}	24 8	24 8	37 5	38 5	33 5	29 0	26 5	24 7	23 0	
Avg EI x 10^{-6}	5 2576	5 2576	2 1225	2 1791	1 8961	1 6414	1 4999	1 3980	1 3018	
Avg EA x 10^{-6}	9 7241	9 7241	3 7575	3 8577	3 3567	2 9058	2 6553	2 4749	2 3046	
Support tube Weight	1 471	2 474	4 337	3 169	3 765	4 492	3 008	3 180	3 005	0 826
Support tube Mass*	2 59502	0 006411	0 011238	0 008212	0 009756	0 011640	0 007794	0 008240	0 007787	2 59335
Pressure tube Weight (includes displaced water)		1 535	1 507	1 158	1 322	1 577	1 056	1 117	1 055	
Pressure tube Mass		0 003978	0 003905	0 003001	0 003426	0 004086	0 002736	0 002894	0 002734	

* Mass includes additional 1000 lb at Grid Points 1 and 10

For the pressure tube

A = 0 4599
I = 0 3423
E = 10 x 10^6

Fig 47 Computer Model, Lateral Support System Analysis

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A sketch of the equivalent computer model is provided by Fig 47 The model is subdivided into 18 mass points with large masses at each end where the forcing function is introduced per a free-free beam The subdivision of temperature, mass and rigidities is provided in tabular form

It should also be noted that the mass of displaced water is included within total mass distribution of the aluminum pressure tube However, hydrodynamic drag damping is not included since its influence was determined to be of little significance compared to the 4 25% material damping in the system Calculations demonstrating this fact are included below

a Calculated damping ratio for anticipated hydraulic damping

The equation of motion for a linear oscillator driven at undamped natural frequency is

$$m\ddot{x} + 2m\beta\omega\dot{x} + m\omega^2 x = P \sin \omega t$$

where

$m\ddot{x}$ = inertia force

$2m\beta\omega\dot{x}$ = linear damping force

$m\omega^2 x$ = spring force = kx

β = damping ratio (c/c_{crit})

ω = undamped natural frequency

m = system mass

Anticipated hydraulic damping force, F_H, is

$$F_H = \frac{1}{2}\rho_w C_D A \dot{x}^2$$

where

ρ_w = mass density of 300° F water

$$= \frac{57\ 2}{1728(386)} = 8\ 6(10)^{-5}\ \frac{\text{lb-sec}^2}{\text{in}^4}$$

A = 2 5ℓ, lateral area of aluminum tube

C_D = 1

Assume x is approximately 10 in /sec

$$F_H = \left(\frac{1}{2}\right) 8\ 6(10)^{-5} 2\ 5\ell\ 10x = 0\ 00108\ell x \qquad (28)$$

Linear damping force of oscillator is

$$F_o = 2m\beta x$$

The weight of the composite structure is approximately 0 386 lb/in x overall length ($\approx$ 50 in)

$$m = \frac{0\ 386\ell}{386 \text{ in /sec}^2} = 0\ 001\ell$$

$$\omega = 460 \text{ radians/sec}$$

$$F_o = 0\ 001\ell\ 2\beta\ 460x = 0\ 92\ell\ \beta x \qquad (29)$$

Equating Eq (28) with (29)

$$F_H = F_o$$

$$0\ 00108\ell\ x = 0\ 92\ell\ \beta x$$

This yields $\beta = c/c_c = 0\ 00117$ or 0 11% damping, considered negligible compared to 4 25% contributed by the material internal friction damping

Since only the material or hysteresis damping is included in the design models, only the UB038 and UB040 programs were necessary for solution The more complex differential equation programs could be eliminated since the damping proportional to mass uncoupled the equations Only a system amplification factor or the actual damping percentage, in this case 4 25%, could be a direct input to the program The program has the capability to use either input For interest, applying Eq (27)

$$Q = \frac{1}{2(0\ 0425)}$$

$$= 11\ 77$$

The vibrational characteristics and stress profile study of the design model consisted of examining results corresponding to an arbitrarily more rigid pressure tube and substituting a spring support at the exit end support To reduce confusion, the nomenclature relating to the design model variations will be summarized as follows

(1) Design Model 1

(a) Material damping = 4 25%

(b) Three springs, locations and spring constants previously described in Fig. 46

(c) Simple support between support and pressure tubes at exit end

(d) Frequency = 47 3 cps

(2) Design Model 1A

(a) Same as Model 1 except that the rigidity of the support tube is doubled Note that the basic design involved a tube of 2 50-inch OD and t = 0 060 inch, resulting in a section moment of inertia of 0 3423 in ^{4} Therefore, for Model 1A, I = 6846 in ^{4}, which corresponds to a wall thickness of 0 12 inch

(b) Frequency = 58 6 cps

(3) Design Model 1B

(a) Material damping = 4 25%

(b) Four springs, three of which are the same as Model 1A, the fourth is substituted for the exit end simple support and the spring constant is 14,000 lb/in

(c) Frequency = 56.5 cps

(4) Design Model 1C

(a) Same as Model 1 except that the aluminum pressure tube receives a third support, a simple support at Station 25

(b) Frequency = 101 7 cps

Figures 48, 49, 50 and 51 present the deflections and bending stresses developed in both the support and pressure tubes as a function of station for these model variations Table 14 provides the transverse load in pounds for each spring and the exit end simple support

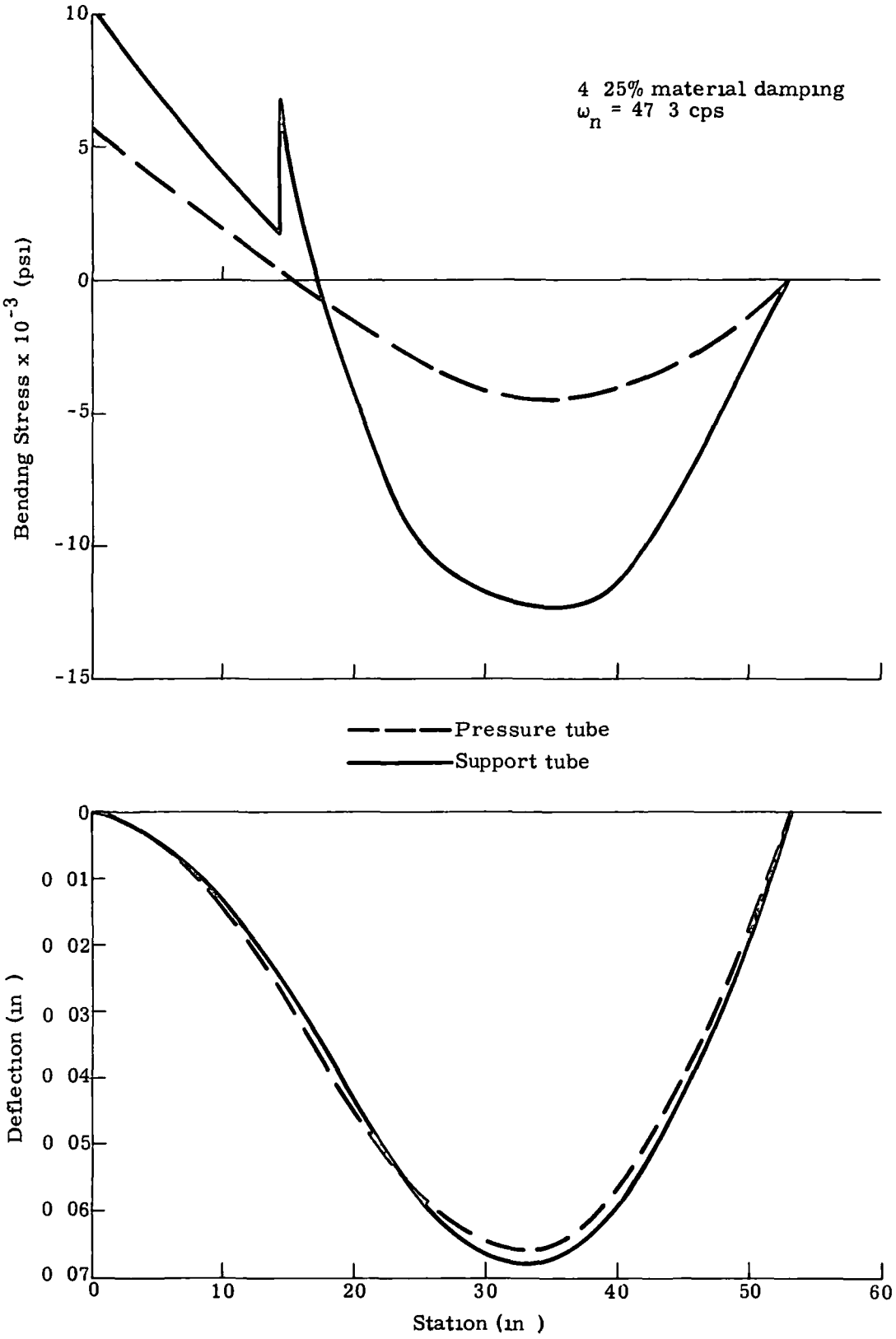


Fig 48 Design Model 1, Bending Stress and Deflections in Support and Pressure Tubes as a Function of Axial Station

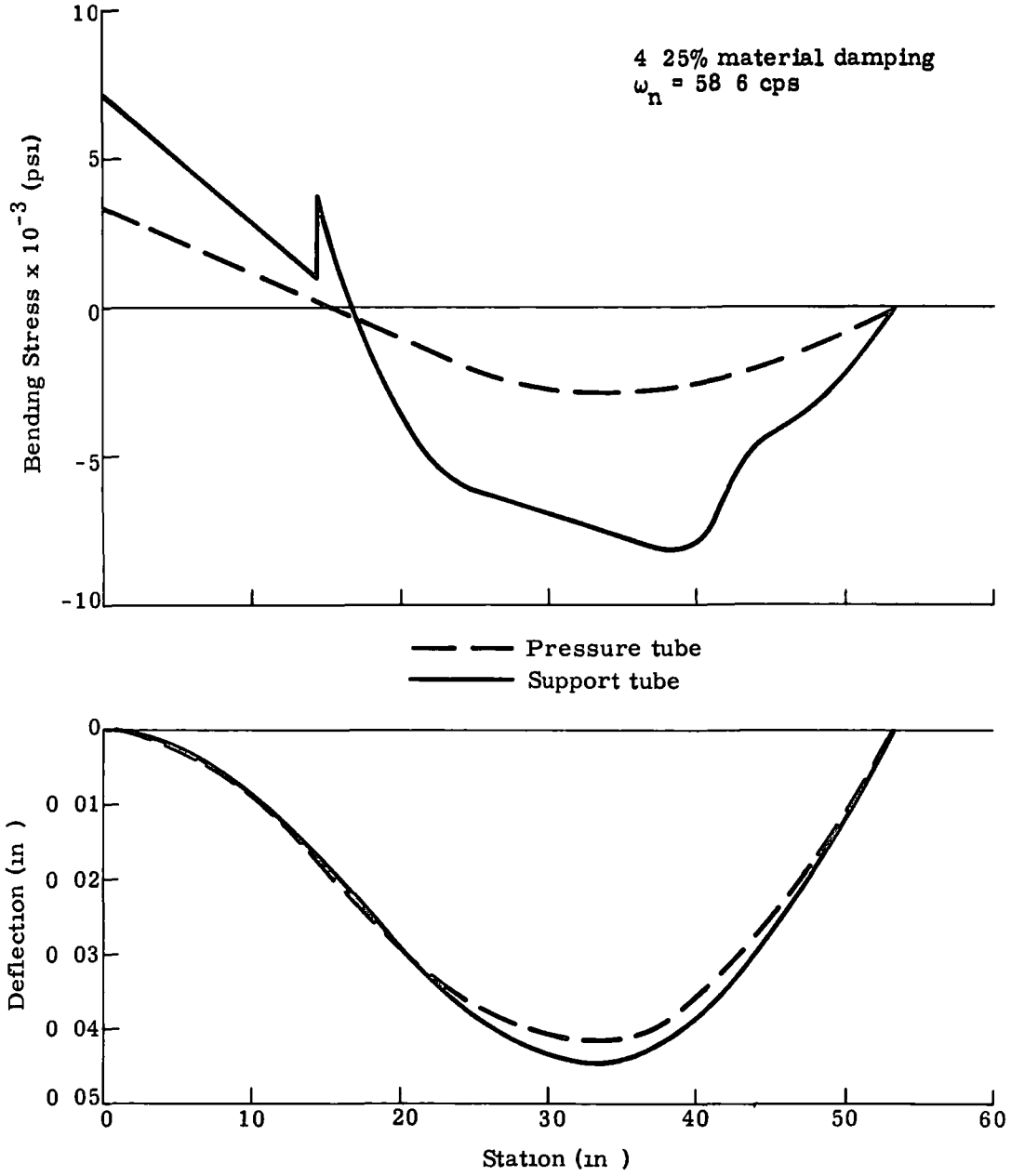
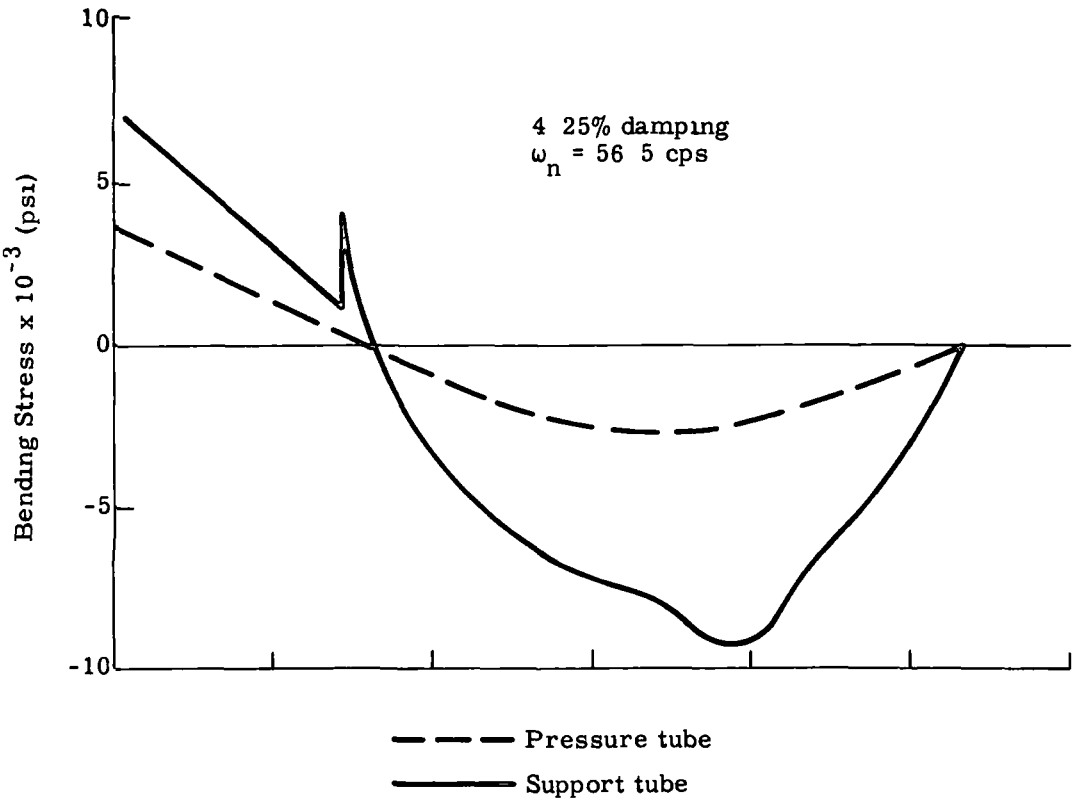


Fig 49 Design Model 1A

* Same as Model 1 except pressure tube I_2, has been doubled



* Same as Model 1A except 14, 000-lb/in spring replaces simple support between tubes at Station 53 25

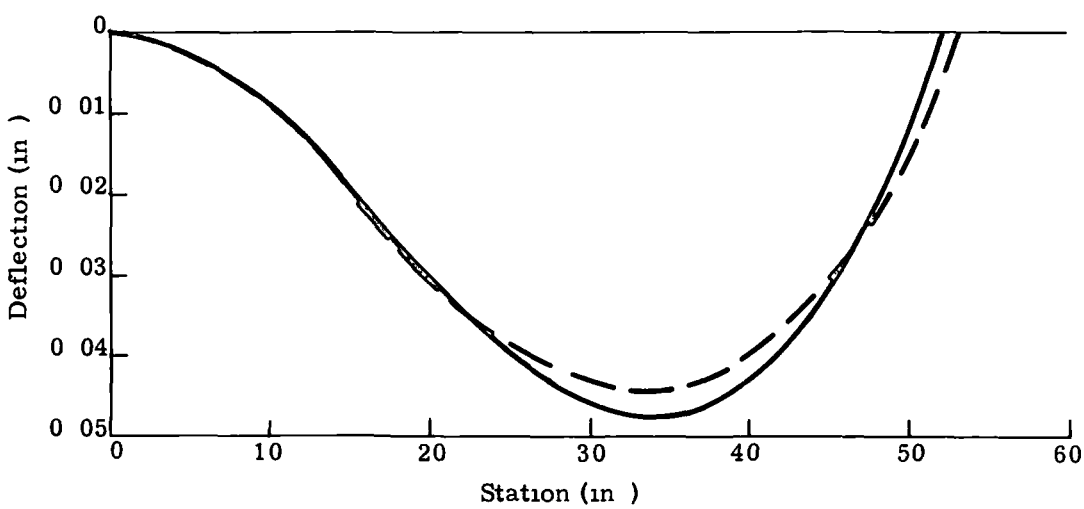


Fig 50 Design Model 1B *

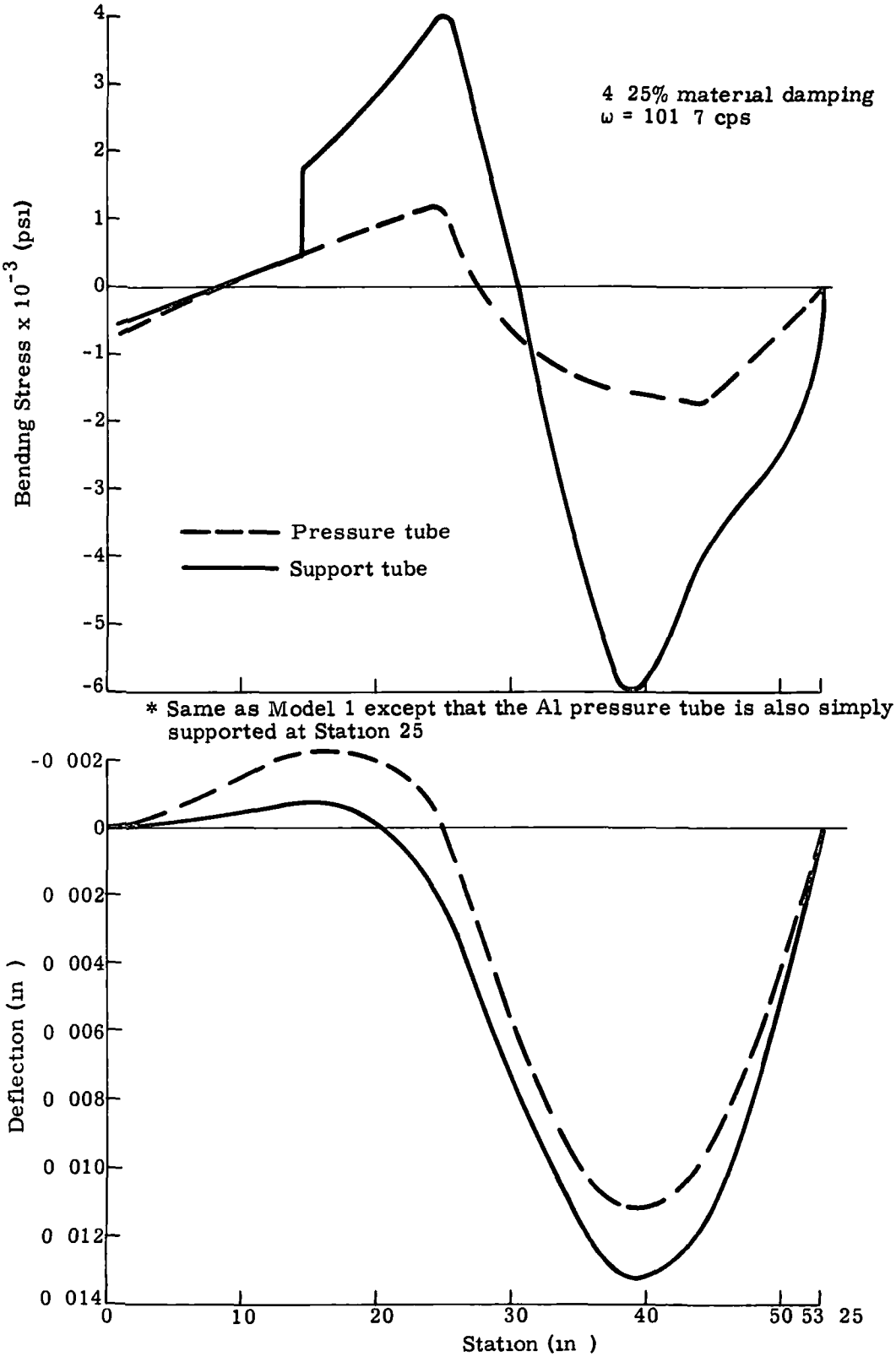

4 25% material damping
ω = 101 7 cps
Bending Stress x 10^-3 (psi)
Pressure tube
Support tube
* Same as Model 1 except that the Al pressure tube is also simply supported at Station 25
Deflection (in)
Station (in)

Fig 51 Design Model 1C *

TABLE 14

Spring and Simple Support Loads for Design Models

Design Model Designation	Spring or Simple Support Load (lb)				
	1	2	3	4	Simple Support
1	10 45	47 8	44 3		99.6
1A	37 8	64 5	51 6		119 2
1B	37 1	73 2	31 8	110 0	
1C	64 5	36 6	42.6		52 9

From the support tube stress profile for Model 1, the inlet end bending stress is 9969 psi as taken from Fig 48 This stress is derived solely as a result of bending and does not include the discontinuities resulting primarily from thermal displacements and relative rigidities Discontinuity stresses are discussed in detail in another section of this report The interface between the 0 060-inch thick columbium and 0 015-inch thick molybdenum occurs at Station 14 5 Again, disregarding discontinuities, the stresses shown on Fig 48 are 6547 and 1749 psi The bending stress for a thin cylinder is given by

$$\sigma = \frac{M}{R^2 t}$$

or is approximately inversely proportional to the thickness, t, assuming R is not changed greatly Therefore, for a check on the program results,

$$\frac{t_{cb}}{t_{mo}} = \frac{0\ 060}{0\ 015} = 4$$

whereas

$$\frac{\sigma_{mo}}{\sigma_{cb}} = \frac{6547}{1749} = 3\ 75$$

Considering the mean radii,

$$\frac{\sigma_{mo} R_{mo}^2}{\sigma_{cb} R_{cb}^2} = \frac{6547(1\ 0625)^2}{1749(1\ 040)^2} = 3\ 91 \cong 4$$

The maximum bending stress occurs at Station 35 and is approximately 12,300 psi The stress distribution is continuous in the pressure tube with a maximum value of about 4500 psi

This stress level of 4500 psi is quite low in magnitude although the hoop compressive stress resulting from external moderator water pressure has not been included This bending stress must be evaluated against potential fatigue failure since there will be approximately three million cycles (at 80 cps) over the 10-hour lifetime

Assuming a support tube at 300° F and manufactured from 6061-T6 aluminum alloy,

$$\sigma_y = 29,000 \text{ psi at } 300° \text{ F}$$

Therefore, an estimated endurance limit based upon 60% σ_y will be 17,400 psi

The three spring loads (Ref Table 14) are 10 45, 47 8 and 44 3 pounds, respectively, from entrance to exit end It is important to realize, however, that one spring is not required to take a total load of 44 3 pounds. This load may be circumferentially distributed in an annular set of springs at two or three axial locations in the close proximity of the station under consideration (Station 43 8 in this example) The number of springs required to spread these loads is dependent upon the amount of local ring reinforcement allowable due to diameter constraints Design tradeoff is necessary to obtain configuration efficiency or optimization between sets of springs required, number of springs per set and length and thickness of ring reinforcement

As previously described, the 1A model has incorporated a more rigid pressure tube having a bending rigidity, EI, equal to twice that of Model 1 Figure 49 shows that the reduction in maximum bending stress is rather significant The maximum stress occurring at Station 39 is approximately 8000 psi or a reduction of 35% from the previous case As the rigidity of the pressure tube is increased, the spring load effect is more noticeable in the support tube bending stress distribution The limiting case is, of course, an infinitely rigid pressure tube This is illustrated in Fig 52 which presents some results of earlier investigations of bending stress distributions assuming a rigid foundation This portion of the study was completed analytically without use of a computer program The stress distribution was obtained simply by examination of a cantilever beam under a 10-g lateral load factor Five springs were introduced and the final stress distribution was based upon beam and spring displacement compatibility

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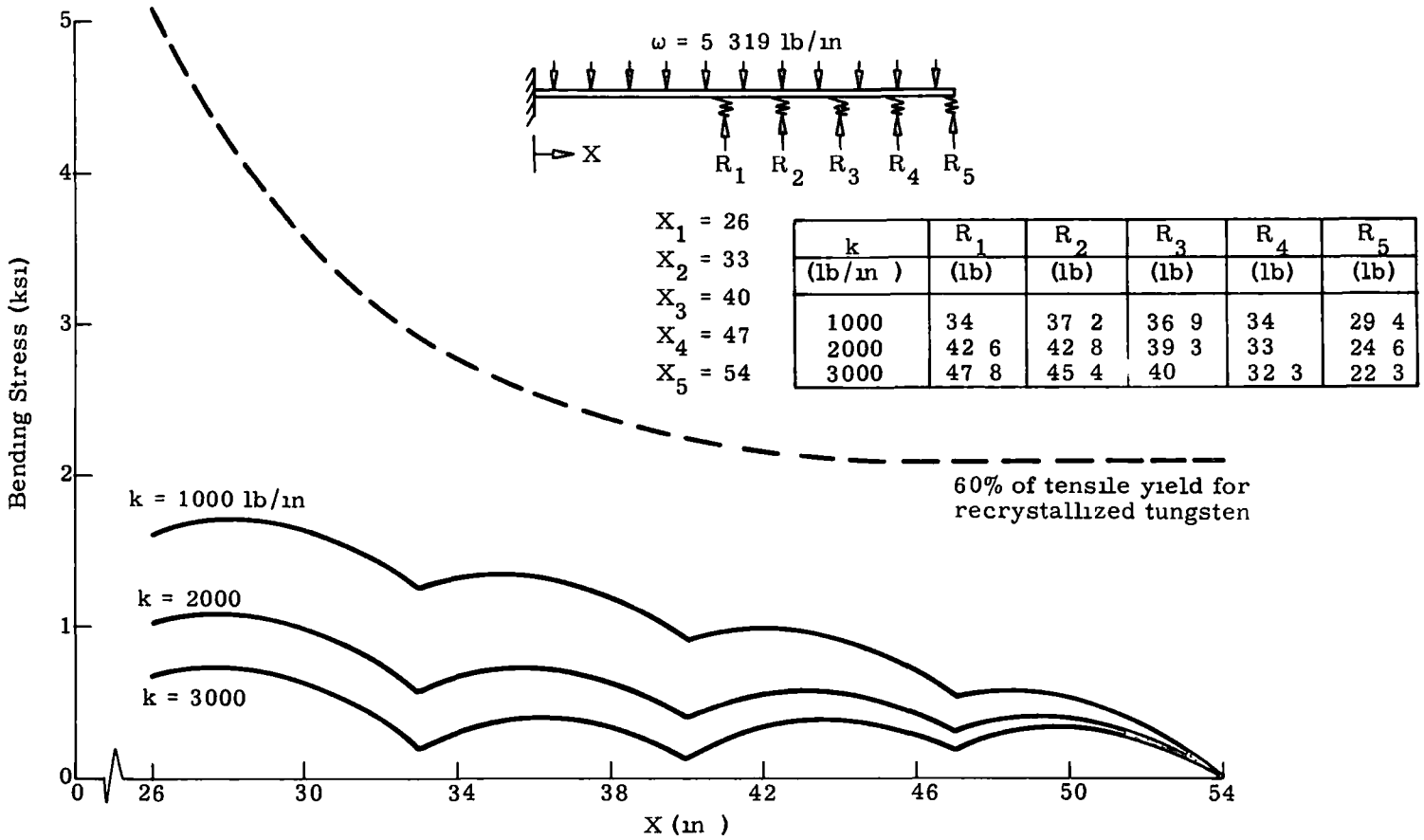
ω = 5 319 lb/in
X
R1 R2 R3 R4 R5
X1 = 26
X2 = 33
X3 = 40
X4 = 47
X5 = 54
60% of tensile yield for recrystallized tungsten
k = 1000 lb/in
k = 2000
k = 3000
Bending Stress (ksi)
X (in)
0 26 30 34 38 42 46 50 54
0 1 2 3 4 5

k (lb/in)	R_1 (lb)	R_2 (lb)	R_3 (lb)	R_4 (lb)	R_5 (lb)
1000	34	37 2	36 9	34	29 4
2000	42 6	42 8	39 3	33	24 6
3000	47 8	45 4	40	32 3	22 3

Fig 52 Support Tube Axial Bending Stress as a Function of Axial Location for Five Spring Supports

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NASA CR-72024
MND-3271

Model 1B departed from the concept of a simple support at the exit end by replacing the support with a spring, in this case a dynamic spring constant of 14,000 lb/in. was introduced. Figure 50 indicates that no advantage was realized since the maximum bending stress is 9250 psi in the vicinity of Station 39 The pressure tube rigidity is the same as Model 1A

Model 1C, shown in Fig. 51, again used the exit end simple support between tubes and assumed the original pressure tube rigidity as per Model 1 However, the pressure tube received a third support (at Station 25) which greatly increased the stiffness of the system At Station 39, a peak bending stress of 6000 psi was realized The resonant frequency was 101 7 cps

From the results presented for the various models, the approach taken of varying only one parameter (i e , increasing the rigidity of the pressure tube by increasing its wall thickness, etc) to obtain a final configuration would be, at best, inefficient To meet an acceptable endurance criterion for recrystallized tungsten, the peak bending stress in the higher temperature regions must be held to approximately 2000 psi To accomplish this goal, the following can be done

(1) Increase the pressure tube effective rigidity by

   (a) Increasing tube thickness or providing longitudinal stiffeners

   (b) Adding intermediate support(s) to obtain a multispan effect

   (c) Providing rotation restraint at exit end

(2) Increase thickness of support tube (the increased rigidity should offset the increase in mass)

(3) Provide more spring locations on the support tube It must be noted that this approach is limited in effectiveness by the inherent stiffness of the pressure tube, but it does have the beneficial effect of reducing local loads on the support tube

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IV DEVELOPMENT RECOMMENDATIONS

A OBJECTIVE

During the course of a preliminary design effort, the future work required to continue meaningful development of a prototype fuel assembly is defined The following programs are recommended

B RECOMMENDATIONS

1 Lateral Support System

Certain approaches to finalizing an acceptable spring device arrangement and the associated required stiffnesses were developed under the present contract It remains to examine these approaches with the computer code and develop a reference design lateral support system in which combined stress levels meet the design criteria established

This will probably require stiffening of the aluminum pressure tube either by increasing the effective tube wall thickness or by incorporating a midspan support for the tube within the TWMR structure

After spring support device location and desired spring rate are specified, the devices may be examined in detail both by analysis and prototype hardware fabrication It is recommended that dynamic spring constants be obtained at temperature for candidate spring device designs High temperature tests run for a period of several hours, with thermal cycling, will be necessary to evaluate the ability of recrystallized refractory metals to perform reliably with rapidly fluctuating internal stresses

2 Support Tube

Completion of analysis on the required support devices discussed will lead to detailed specification of the required local reinforcement of the support tube Brazed joints in the support tube should be tested under operating conditions of temperature and stress

3 Exit End

The insulation system must be studied in more detail, using a two-dimensional digital code analysis including the internal heat generation from gamma rays and neutrons Hydrodynamic studies and development tests must be designed to ensure that the required heat transfer coefficient between the moderator water and the exit end tube sheet can be obtained

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4 Inlet End

Development tests to verify the adequacy of the reference design sealing scheme must be performed using prototype hardware under operating conditions of pressure drop and temperature

The reference design attach nent method must be incorporated into the experimental vibration model in order to determine the effective fixity of the cantilever spring latch configuration This information must then, of course, be factored into the overall prototype lateral support system design

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APPENDIX A

MATERIAL PROPERTIES COMPILATION

Selected Properties of Materials for the TWMR Reactor

Material	Density (lb/in^3)	Thermal Condition (Btu/hr-ft-°R)	Emissivity
Aluminum	0 0978	106 0	0 05
Tungsten	0 697	48 38	0 23
Molybdenum	0 370	65 0	--
Columbium	0 340	26 0	--
Zirconium oxide	0 203	0 55	--

Hydrogen Property Versus Temperature

Temperature (°R)	Thermal Condition (Btu/hr-ft-°R)	$(Cp^{0\ 4}K^{0\ 6}/\ ^{0\ 4})$*
200	0 0526	1 748
400	0 0927	2 058
600	0 1191	2 079
800	0 1446	2 151
1000	0 1692	2 225
1400	0 2178	2 372
1800	0 2578	2 479
2200	0 2934	2 565
2600	0 3222	2 638
3000	0 3492	2 688
3400	0 3787	2 745
3800	0 4176	2 992
4200	0 4698	3 234
4600	0 5328	3 481

* $\frac{Btu^{0\ 8}}{lb}\ ft^{0\ 2}\ hr^{0\ 2}/°R$

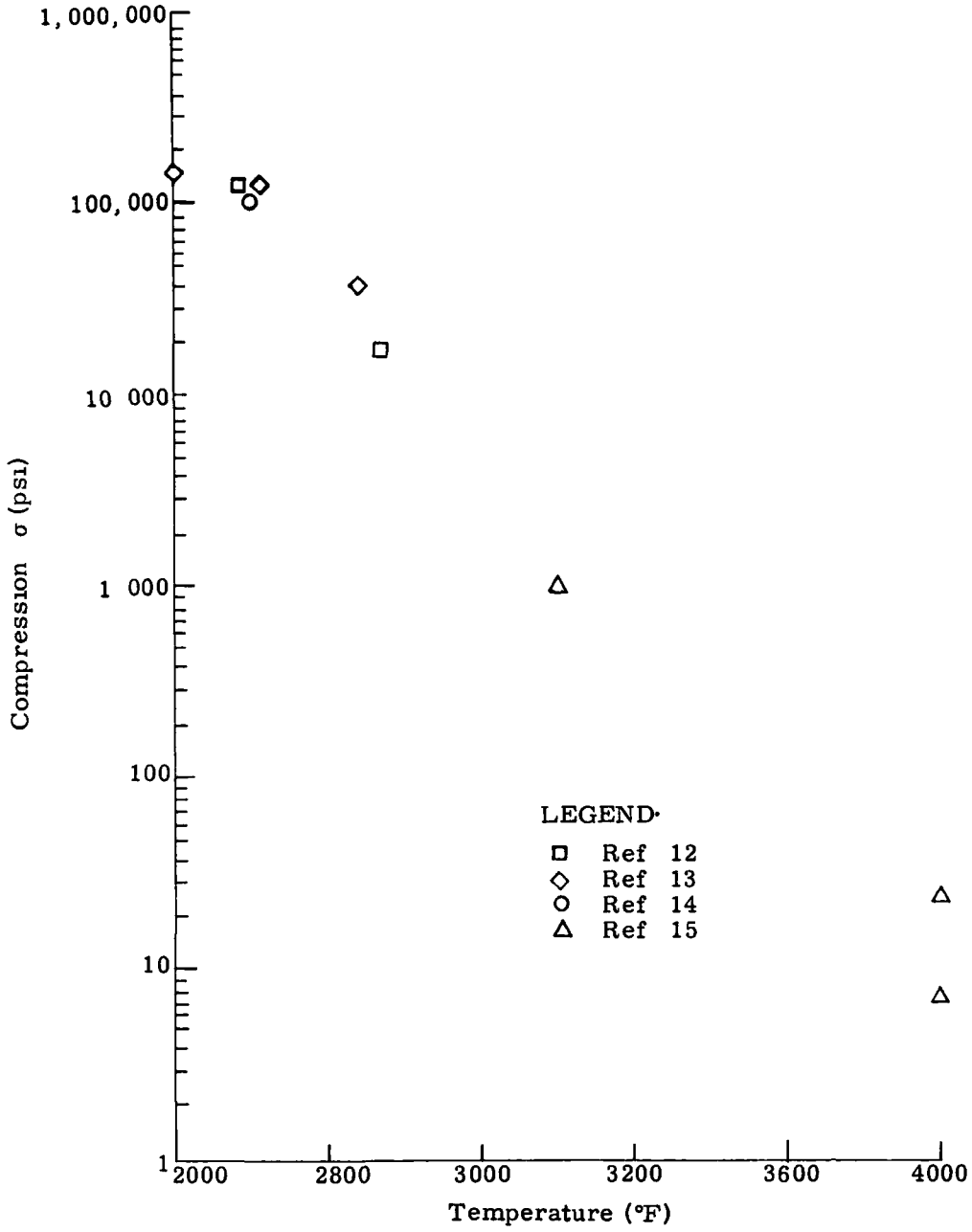

Fig A-1 Zirconia Compressive Strength

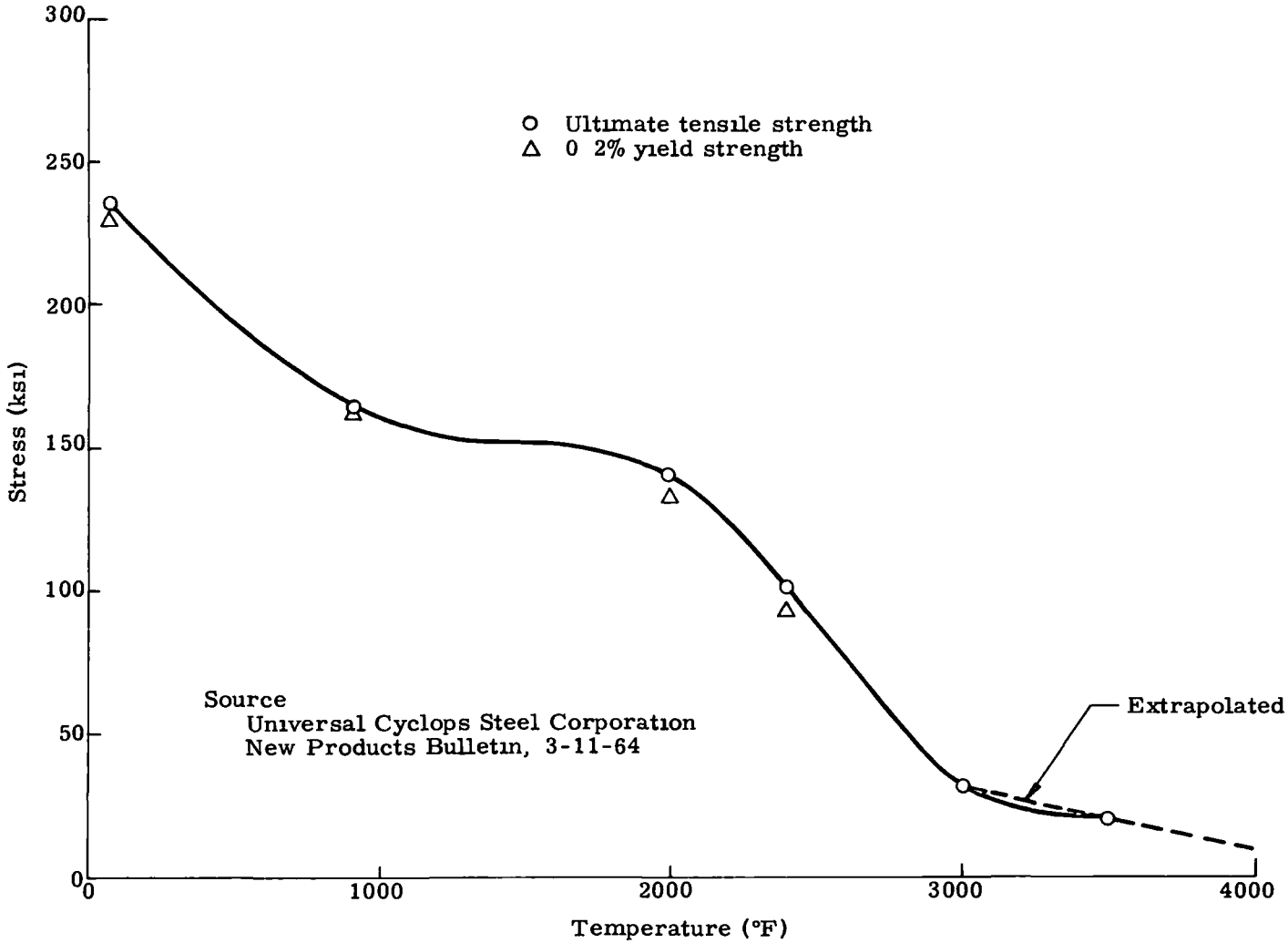

Fig A-2 Tensile Properties of Arc Cast Tungsten-25% Rhenium as a Function of Temperature

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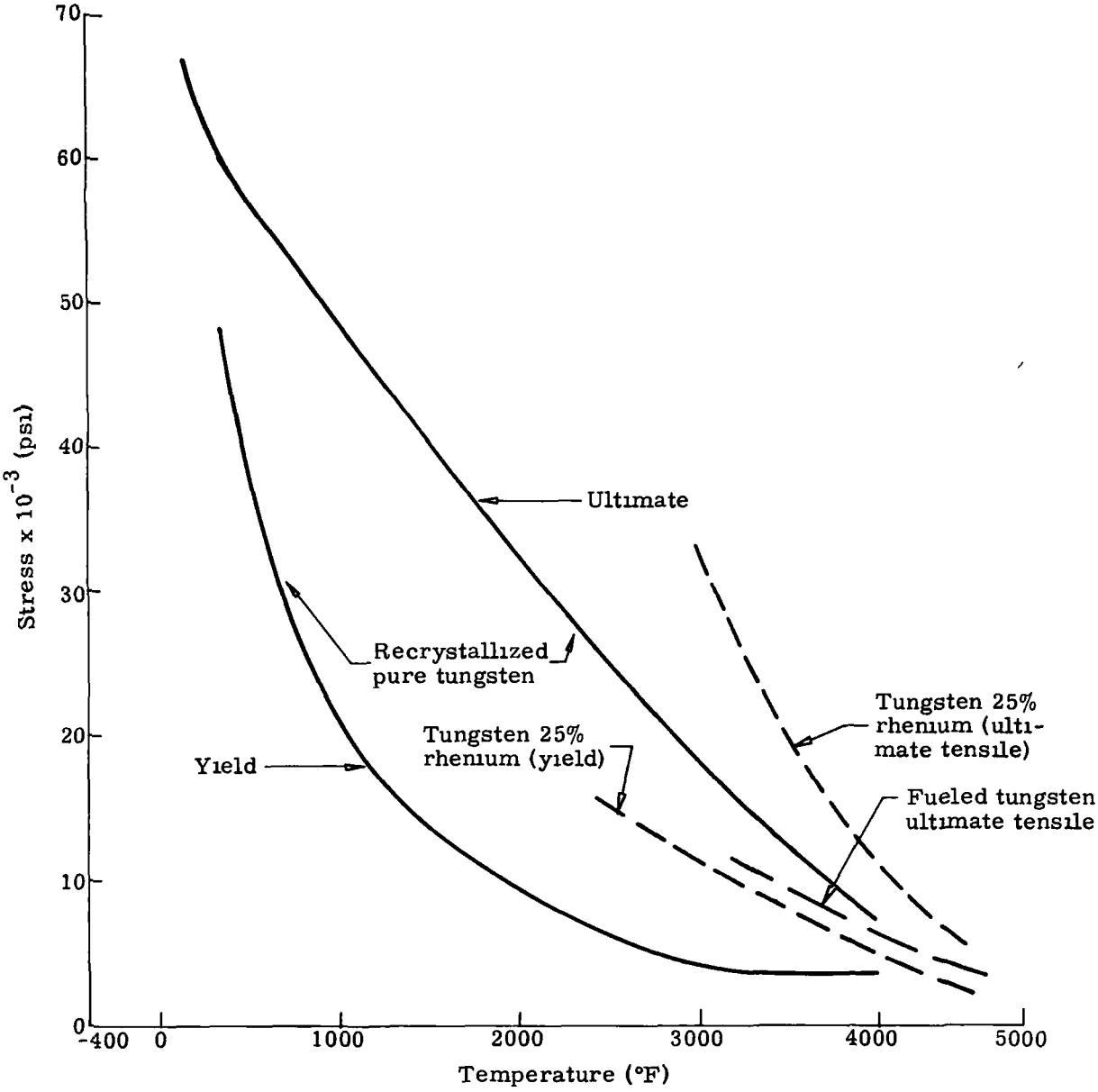

Fig A-3 Tensile Properties of Fueled and Unfueled Tungsten and Tungsten-25% Rhenium

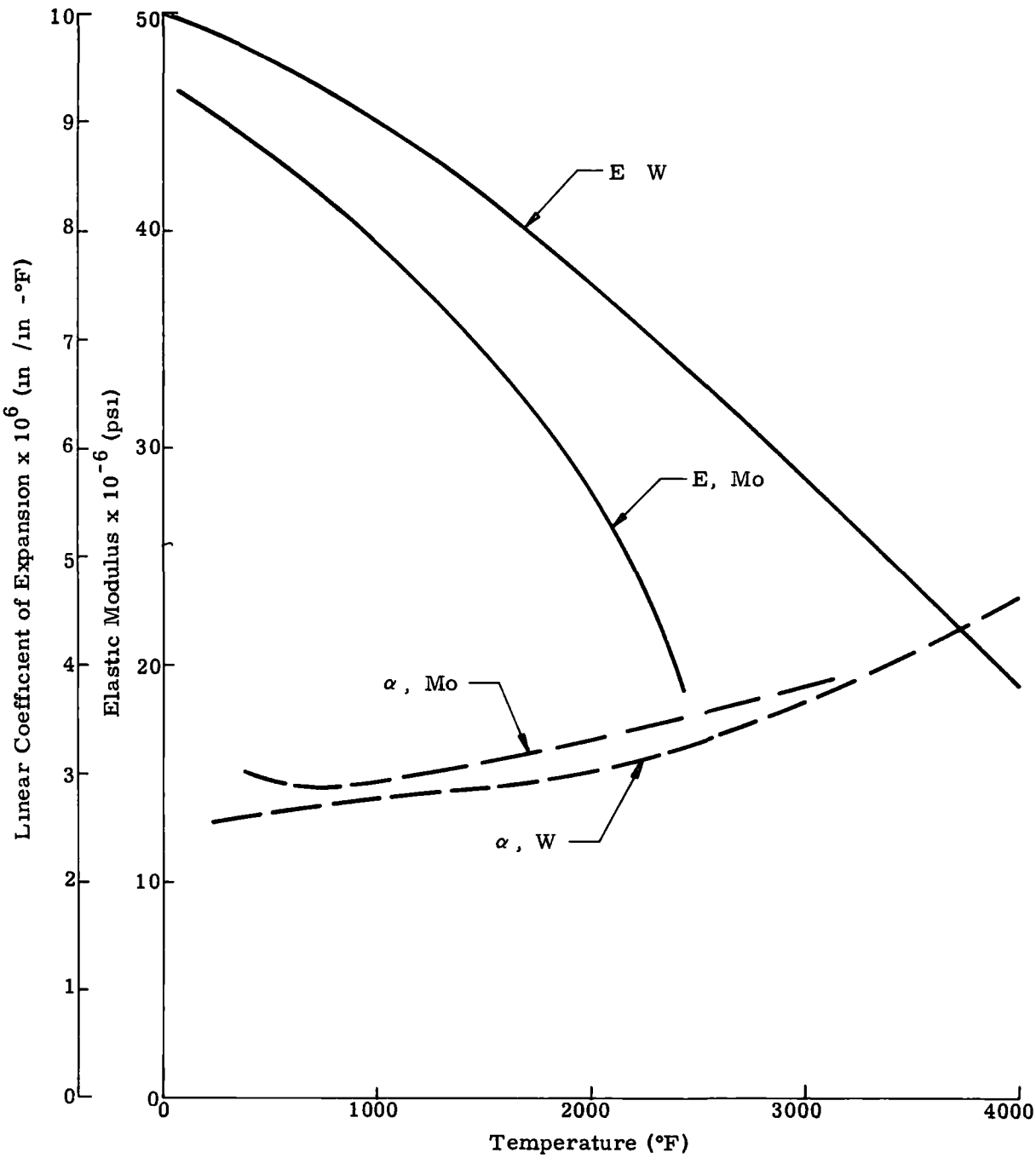

Fig A-4 Elastic Modulus and Linear Coefficient of Expansion as a Function of Temperature for Tungsten and Molybdenum

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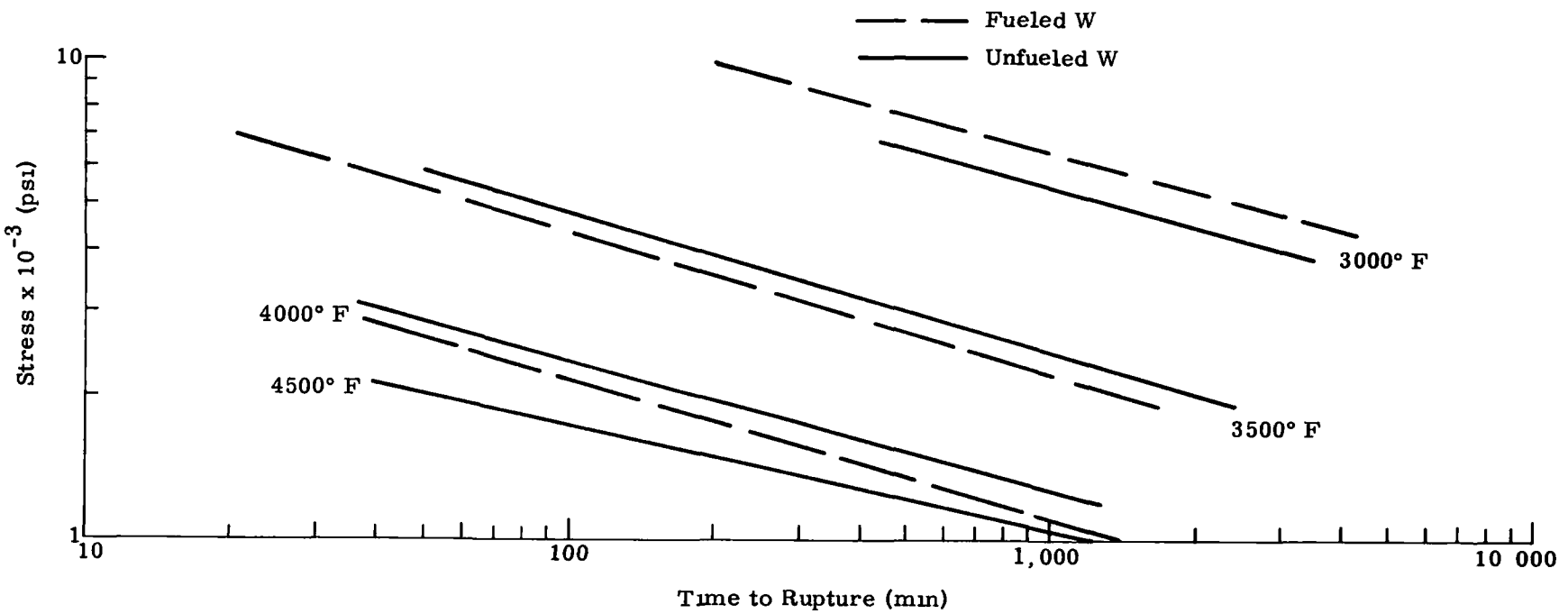

Fig A-5 Stress-to-Rupture Data for Fueled and Unfueled Tungsten as a Function of Time, for Various Temperatures

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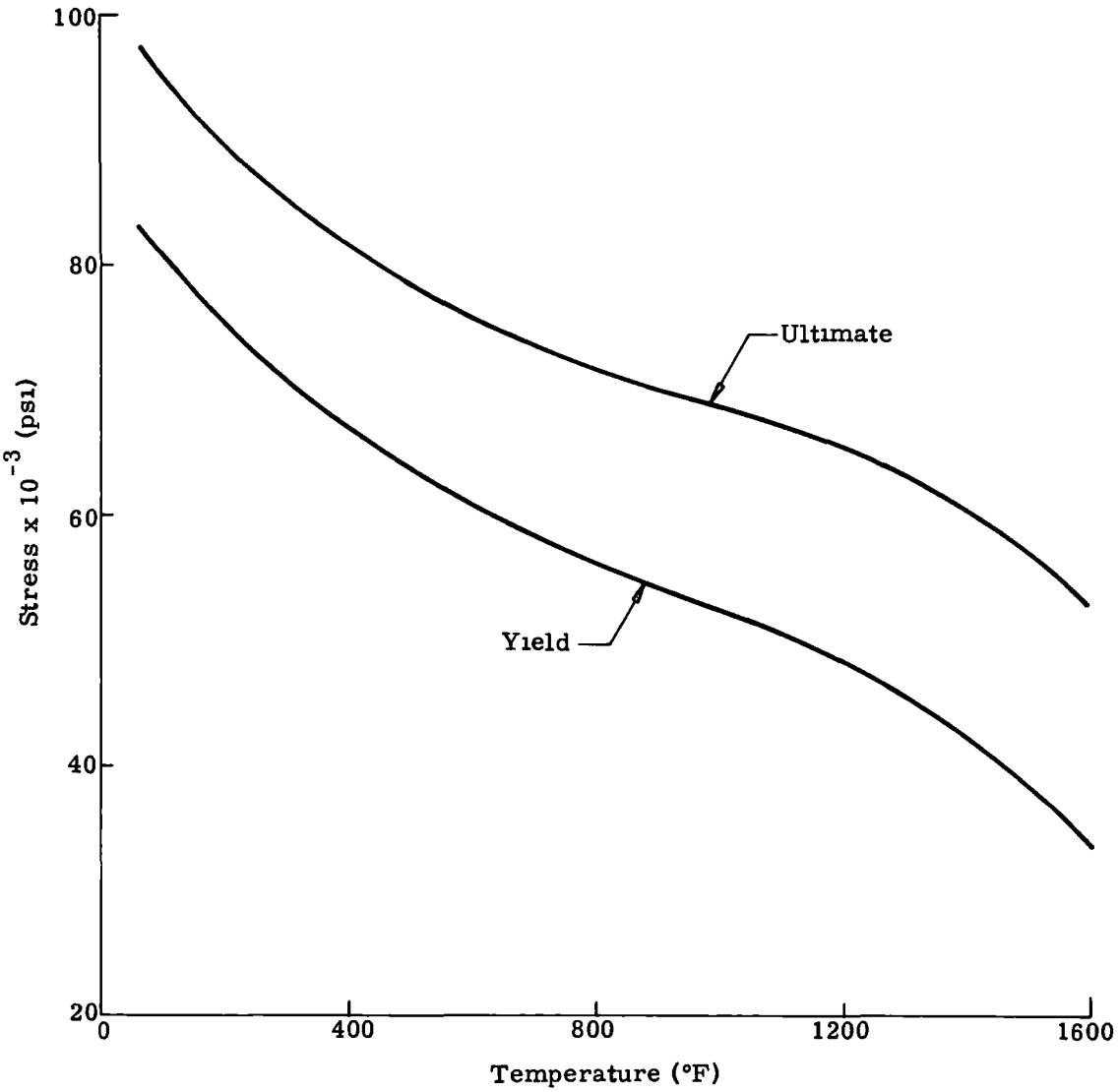

Fig A-6 Tensile Properties of Stress Relieved Molybdenum, as a Function of Temperature

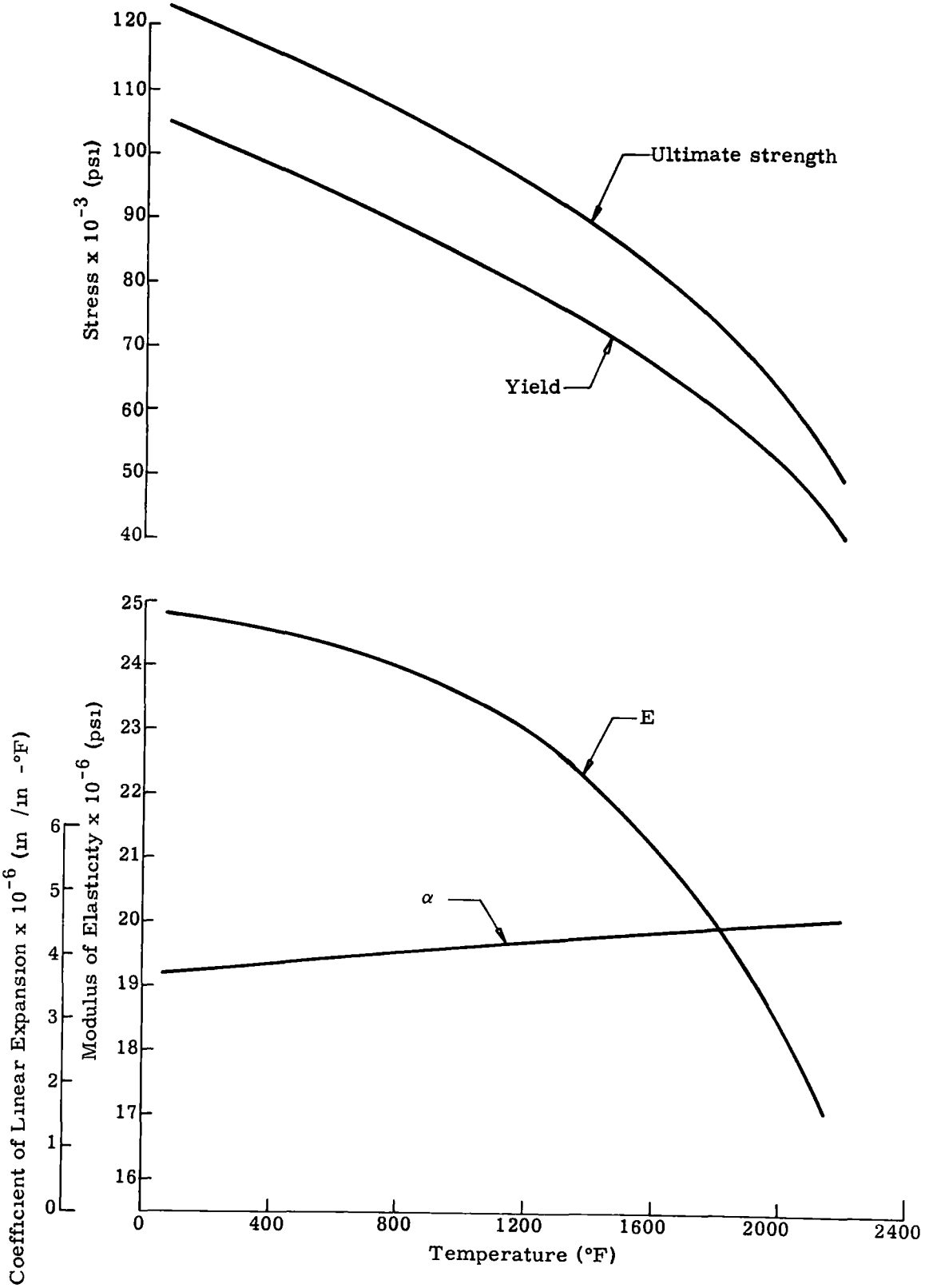

Fig A-7 Mechanical Properties of F-48 Columbium Alloy as a Function of Temperature

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APPENDIX B

A DIGITAL PROGRAM FOR STATIC AND DYNAMIC ANALYSES OF COMPLEX STRUCTURES

by

S Kaufman
D B Hall

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FOREWORD

This report has been prepared by the Structures and Materials staff under a program sponsored by Research Department Task Authorization No 489 (1962)

The authors would like to express their appreciation to T L Clark of the Space Systems Division of the Martin Company for the programming of this problem and its many facets

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SUMMARY

A particular method of calculating the stresses and deflections due to static, thermal and dynamic loadings on a complex structure is presented The equations, which have been programmed for solution on a high speed digital computer, include a technique for expressing the elastic properties of plates and shells by means of skew and triangular networks A systematic method of partitioning composite structures, using a concept involving fictitious reactions, is also introduced

The accuracy of the procedure has been verified by comparison with experimental and theoretical data

LIST OF SYMBOLS

$^{-1}$	matrix inversion (superscript)
$\{\ \}$	column matrix
$[\ ]$	row matrix
A	symmetrical deflection influence matrix for supported structure, area
A_f	symmetrical deflection influence matrix for structure with rigid body freedom
A_h	deflections due to thermal loadings defined by unit (virtual) {P} loads
E	modulus of elasticity
E_o	symmetrical compliance matrix
G	damping matrix
{H}	free thermal deformations
h	plate thickness
I	identity matrix, moment of inertia
K	symmetrical mass matrix
ℓ	length, ℓ'th normal mode
M_1, M_2	internal loads for statically determinate base structure due to unit {S} and {P} loadings, respectively
{P}	static external forces
P*	static and dynamic forces (see Eq (17))
{S}	redundant loading
T	matrix transposition (superscript)
x, y, z	reference cartesian coordinate system

LIST OF SYMBOLS (continued)

$\{ \gamma \}$	element internal loads
$\{ \delta \}$	element deformations
$\{ \eta \}$	deflections
λ	internal load influence matrix for supported structure
λ_f	internal load influence matrix for structure with rigid body freedom
λ_h	internal load matrix for free thermal deformations
μ	Poisson's ratio

I. INTRODUCTION

This report presents a matrix-force method for both static and dynamic analysis of aerospace structures by an element-matrix technique Any structural system, such as a stiffened shell, three-dimensional truss, or a system of connected beams, can be simulated by a number of simple structural elements connected together at grid points The technique of model synthesis and selection of elements and the matrix method of solving for stress, deflection, frequency of natural modes, and dynamic load response, are developed in this report Attention is given to the influence of thermal inputs on the structural loads, stresses and deflections.

A somewhat unusual method of partitioning composite structures is described Partitioning is systematized by supporting all segments independently, with fictitious elastic supports where necessary, considering all connections between segments redundant and finally eliminating the fictitious supports.

The techniques described are particularly well suited to analysis of three-dimensional truss structures, of up to hundreds of elements, where stresses, deflections and vibration frequencies are required. Shells of noncircular cross section with cutouts, stiffeners and internal compartments are also well suited to these methods, particularly when one uses partitioning to permit large numbers of elements, which thereby allows a more accurate representation of the structure

The overall method described in this report is quite versatile. It has been used successfully in handling both the statics and dynamics of swept wings and also to reproduce accurately the first 18 natural frequencies of a cylindrical shell

II STRUCTURAL MODEL

The structural model consists wholly of "elements," the internal loading of which can be represented by force resultants at "grid points " The term "element," in this sense, requires further clarification Consider a simple bar with loads at its two ends The stress can be completely defined by six independent components tension, torque, and two mutually perpendicular bending moments, with their balancing transverse forces, at each end Each of these six independent force systems is considered as being carried by a separate element

Figure 1* illustrates some useful tension, bending shear and twist elements For example, consider the in-plane stresses in a rectangular plate as consisting of shear stresses and orthogonal tensile stresses Lines connecting two grid points of a rectangular network are tension elements, and the enclosed rectangular panels defined by four grid points are shear elements, as described in Fig 1 In this example of in-plane stresses, the element loads represent an average stress integrated over a proper area of the rectangle

Each element has one characteristic load, as previously explained, and one corresponding deformation Deformation in an element can be caused not only by the load in that element, but also by loads in other elements In a rectangular network, for example, tension in one set of elements produces shortening of perpendicular elements through Poisson coupling Elements of various shapes may be employed to fit into desired grid patterns Appendix A describes parallelogram and triangle elements

Reactions are counted as elements For the static analysis, there must be enough reactions to constrain rigid body motion A structure with rigid body degrees of freedom thus must be supplied with fictitious reactions, to be cancelled later by equilibration with inertia forces

As in any discrete element technique, proper selection of elements, with their elastic properties and their geometric arrangement, is a key to successful analysis of the original structure The objectives of the analysis have to be examined as the model is derived For example, a requirement for local stresses or a large number of vibration modes implies a fine network However, the number of elements should not be allowed to get uneconomically large

---

*All illustrations are presented in Appendix B of this report

III STATIC ANALYSIS OF STRUCTURAL MODEL

After a structure has been simulated by a network of elements, deflections and internal loads of the model are calculated by satisfying equilibrium and compatibility conditions

The elements are classified as primary or redundant The primary elements comprise a statically determinate base structure, their number being equal to the number of equilibrium equations at the grid points The choice of these primary elements is, of course, not unique, various determinate sets can be chosen The best sets are the ones that minimize the coupling among the remaining redundant elements, thereby yielding the best conditioned compatibility equations Among these, the best are those utilizing the strongest elements and shortest load paths Therefore, this selection is important for the sake of accuracy

It should be noted that other redundant-handling schemes have been proposed (Refs 1 and 2) These approaches use a concept of self-equilibrating redundant systems, and permit greater leeway in the selection of well-conditioned systems The present method, using primary and redundant elements, was adopted because it permits a simpler and more concise matrix formulation of the equilibrium equations

A EQUILIBRIUM

Structural equilibrium is obtained by a system of equations expressing equilibrium of force and moment at the grid points In matrix notation, this relationship can be expressed as follows

$$T\{R\} + U\{S\} + V\{P\} = \{0\} \tag{1}$$

The matrixes $\{R\}$ and $\{S\}$ represent the internal loads in the primary and redundant elements, respectively $\{P\}$ represents external loadings, and can include discrete forces and moments, and distributed or generalized loadings, such as pressures, complete flight loads, etc The matrixes T, U and V convert these loadings into equilibrium equations at the grid points

The solution of Eq (1) for the primary-element loads (in terms of the redundant-element loads and external loadings) is

$$\{R\} = -T^{-1}U\{S\} - T^{-1}V\{P\} \tag{2}$$

Next, the internal loads in all the elements are assembled into the following expression

$$\{\gamma\} = M_1\{S\} + M_2\{P\} \tag{3}$$

where

$$\{\gamma\} = \begin{Bmatrix} R \\ \overline{S} \end{Bmatrix},\ M_1 = \left[\begin{array}{c} -T^{-1}U \\ \hline I \end{array}\right] \text{ and } M_2 = \left[\begin{array}{c} -T^{-1}V \\ \hline 0 \end{array}\right]$$

B COMPATIBILITY AND DEFLECTIONS

The deformations of elements must be selected so that they are conjugate to the element loads in the virtual work sense (i e , elongation of tension elements, end rotation of beam elements, displacement of supports, etc) These deformations $\{\delta\}$ are

$$\{\delta\} = E_o\{\gamma\} + \{H\} = E_o M_1\{S\} + E_o M_2\{P\} + \{H\} \tag{4}$$

The matrix E_o is a symmetrical compliance matrix which relates the deformation of each element to its own load, as well as loads in neighboring elements This compliance matrix is discussed, with respect to a variety of element types, in Appendix A

The matrix $\{H\}$ represents the free thermal deformation, shrinkage, misfits, etc , in the elements

Compatibility conditions are met through an application of the principle of virtual work the work caused by an internal loading system, resulting from a unit load in each redundant element acting through the actual deformations, is equal to zero The matrix M_1 represents the element loadings due to unit loads in the redundant elements, each column corresponds to a unit load in the appropriate redundant Then the matrix of virtual work due to all the unit redundant loads is $M_1^T\{\delta\}$, and

$$M_1^T\{\delta\} = \{0\} \tag{5}$$

Substituting Eq (4) in Eq (5), setting $g = M_1^T E_o M_1$, and solving for the redundant element loads, gives

$$\{S\} = - g^{-1} M_1^T E_o M_2 \{P\} - g^{-1} M_1^T \{H\} \quad (6)$$

Substitution of Eq (6) in Eq (3) gives the internal loads in terms of external loading and thermal expansion

$$\{\gamma\} = \lambda \{P\} + \lambda_h \{H\} \quad (7)$$

where

$$\lambda = (I - M_1 g^{-1} M_1^T E_o) M_2$$

and

$$\lambda_h = - M_1 g^{-1} M_1^T$$

The substitution of Eq (7) in Eq (4) gives the now compatible deformations in all the elements

$$\{\delta\} = E_o \lambda \{P\} + (I + E_o \lambda_h) \{H\} \quad (8)$$

Just as deformations had to be conjugate with element loads, deflections $\{\eta\}$ must be defined to make them conjugate with the external loadings $\{P\}$, so that they can be calculated by virtual work The virtual work is made up of the products of deformations $\{\delta\}$ (Eq (8)), from whatever source, and the internal loads from virtual (unit) external loadings, $\{P\}$, identifiable as λ (Eq (7)) Whence,

$$\{\eta\} = A \{P\} + A_h \{H\} \quad (9)$$

where

$$A = \lambda^T E_o \lambda$$

and

$$A_h = \lambda^T (I + E_o \lambda_h)$$

The symmetric matrix A is known as the deflection influence matrix for the supported structure Other methods of deriving A are possible One of the simplest is to substitute M_2^T for λ^T in the expression for A (and A_h as well) This is possible because compatibility means, among

other things, that deflections of all stable base systems (including the one used) must be identical (In fact, Eq (5) is commonly interpreted as simply the statement that deflections measured by virtual loads {S} must vanish)

Another method is to combine Eq (3), Eq (5) and $\{\eta\} = M_2^T$ x (Eq (4)) into a single large matrix which, when reduced by Gaussian elimination, yields Eqs (7) and (9) Experience indicates, however, that the form $\lambda^T E_o \lambda$ assures symmetry and holds accumulated errors to a minimum at the expense of little added computer time

As stated prior to writing Eq (9), the deflections, calculated by virtual work, are conjugate with the loads Unit forces "measure" ordinary deflections Moments yield rotations Some more generalized loads also yield significant and useful results A uniform internal unit pressure in a closed vessel "measures" the volume change due to any loading Loads in the form of trigonometric series and Legendre polynomials yield deflections which are also in the form of trigonometric series and Legendre polynomials However, a complete A matrix may also contain other terms with no practical meaning For this reason, and because only those loads and deflections associated with masses are used in development of dynamic equations, {P} , A, and $\{\eta\}$ usually will be partitioned in an appropriate manner

C REMOVAL OF RIGID BODY CONSTRAINTS

As previously stated, the static analysis required enough reactions to constrain rigid body motion, with fictitious reactions supplied if necessary This section explains the method of eliminating such fictitious reactions in structures which have one or more rigid body degrees of freedom The fictitious reactions must comprise a statically determinate system In essence, the scheme is to calculate inertia forces to balance applied loads, and to apply the loads and inertia forces simultaneously, automatically causing the fictitious reactions to vanish

The method utilizes the {P} submatrix of forces (and possibly moments) applied at a set of mass points, and the corresponding square A submatrix The deflections A {P} thus will correspond to the degrees of freedom of a dynamical system

The inertia forces at each mass point can be completely described in terms of six independent rigid body degrees of freedom $\{\xi\}$ For convenience, consider these quantities to correspond to three orthogonal lineal accelerations and three orthogonal angular accelerations along the reference cartesian coordinate system and referred to the

origin (a^x, a^y, a^z, α^x, α^y, α^z) In matrix notation, the inertia forces at the mass points are $-KD\{\xi\}$, where the D matrix transfers the six rigid body accelerations at the origin to the mass points and the K matrix (mass matrix) converts these accelerations to forces

Consider the general case where the dynamic degrees of freedom at mass point i consist of three translations and three rotations along an orthogonal set of axes (r, s, t attached to i) The D and K matrices are assembled from component contributions from each mass point i One of these component portions is shown in complete generality in Fig 2 In particular, the portion of the mass matrix associated with mass point i is seen to contain first and second moments of inertia in addition to the mass concentrated at that point In Fig 2, the a, b, c's, with proper subscripts, refer to the direction cosines along r, s, t, with respect to the reference cartesian coordinate system x, y, z, M^1 denotes the mass at i, and the components of the first (H's) and second (I's) mass moments are computed as follows

$$H_u^1 \ (u = r, s, t) = \int u \, d M^1,$$

$$I_{rr}^1 = \int (s^2 + t^2) \, d M^1, \ I_{rs}^1 = \int rs \, d M^1, \text{ etc}$$

In some applications, the need for rotational degrees of freedom at grid points can be eliminated by a device of inertia coupling Consider, as an elementary example, a distributed mass (M total, radius of gyration r) centered between two points (1 and 2) at a distance b apart Consider, further, that deflections are restricted to a direction normal to the line between 1 and 2 Then, the inertia forces from accelerations η_1, η_2 are

$$- \begin{bmatrix} M(1/4 + r^2/b^2) & M(1/4 - r^2/b^2) \\ M(1/4 - r^2/b^2) & M(1/4 + r^2/b^2) \end{bmatrix} \begin{Bmatrix} \ddot{\eta}_1 \\ \ddot{\eta}_2 \end{Bmatrix} \tag{10}$$

The net loads on a rigid body subject to external {P} loads are given by

$$\{P\} - KD\{\xi\} \tag{11}$$

The six rigid body equations of equilibrium are

$$D^T \left[\{P\} - KD\{\xi\} \right] = \{0\} = D^T \{P\} - C\{\xi\} \ , \tag{12}$$

where $C = D^T K D$ is a 6 x 6 symmetrical matrix describing the zero, first and second mass moments about the origin relative to the reference coordinate system

After premultiplying Eq (12) by C^{-1} and substituting the results in Eq (11), the net loads on the structure are

$$(I - KF)\{P\} \tag{13}$$

where $F = DC^{-1}D^T$ The internal loads for the $\{P\}$ loading are

$$\{\gamma\} = \lambda (I - KF)\{P\} = \lambda_f \{P\} \tag{14}$$

The deflections for the unconstrained structure, using the concept of virtual work, become

$$\{\eta\} = \lambda_f^T E_o \lambda_f \{P\} = A_f \{P\} \tag{15}$$

where

$$A_f = (I - FK) A (I - KF) \tag{16}$$

A_f is the symmetrical deflection influence matrix for the unconstrained structure, obeying Maxwell's reciprocity relationships

A_f is a singular matrix, as can be deduced on physical grounds There are six linear independent force vectors which result in null displacement vectors corresponding to rigid body translation and rotation Hence, any linear combination of these six vectors can be added to a given force vector without causing change in the displacement vector

A partially constrained structure (less than six rigid body degrees of freedom) is easily handled by the above techniques by striking out or coupling appropriate columns of the D matrix

IV DYNAMIC ANALYSIS OF STRUCTURAL MODEL

The time-dependent inertia, damping and external forces acting at the grid points of the model are, in matrix notation

$$P^*(t) = -K\eta(t) - G\eta(t) + P(t) \tag{17}$$

The linear equations of motion are

$$\eta(t) = A\,P^*(t) \tag{18}$$

and the internal stresses are

$$\gamma(t) = \lambda\,P^*(t) \tag{19}$$

A and λ are replaced by A_f and λ_f when there are rigid body degrees of freedom

The dynamic analysis is based on a modal method (Ref 3) The presence of damping makes the procedure an approximate one arbitrary restrictions must be placed on the damping terms In fact, Eq (17), postulating that damping is proportional to velocity, already imposes one such restriction

The approximating procedure consists primarily of calculating normal modes for the inertia forces alone, transforming the equations of motion (Eq (18)) into these normal coordinates, manipulating the damping terms to preserve the modal form, and finally, solving the modified equations of motion

The calculation of normal modes in the case of a nonsingular diagonal mass matrix is fairly standard In the general case of a symmetric positive definite mass matrix, an additional transformation (Ref 4) is required

$$d = u^T K u, \text{ or } K = u\,d\,u^T \tag{20}$$

where d is a diagonal matrix of the eigenvalues of K, and u is the square orthogonal matrix ($u^T = u^{-1}$) of associated eigenvectors

Let

$$\eta(t) = u\,d_{1/2}^{-1}\,w(t) \tag{21}$$

where $d_{1/2}$ is the square root of d

Making this substitution and premultiplying by $d_{1/2} u^T$, Eq (18) becomes

$$L\,w(t) + d_{1/2} u^T A G u d_{1/2}^{-1} \dot{w}(t) + v(t) = d_{1/2} u^T A P(t) \qquad (18a)$$

where

$$L = d_{1/2} u^T A u d_{1/2}$$

Next, the nontrivial eigenvalues of the L matrix are obtained These comprise a diagonal matrix $\left(\frac{1}{\omega^2}\right)$, and their associated eigenvectors comprise an orthogonal rectangular matrix x, satisfying the relationships $x^T x = I$ and $x^T L x = \frac{I}{\omega^2}$

Now let

$$w(t) = x\,q(t) \qquad (22)$$

The real deflections (Eq 21) become

$$\eta(t) = Z\,q(t) \qquad (23)$$

where the columns of $Z = u d_{1/2}^{-1} \lambda$ are the mode shapes of the normal modes corresponding to the elements of the diagonal undamped frequency matrix ω Some of the relationships involving Z are

$$\left.\begin{aligned} &Z^T K Z = x^T x = I \\ &\omega^2 Z^T K A K Z = \omega^2 x^T L x = I \\ &\omega^2 Z^T K A = Z^T \end{aligned}\right\} \qquad (24)$$

Substituting (22) in (18a), premultiplying by x^T, and making use of (20) and (24), the equations of motion become

$$\ddot{q}(t) + \alpha\,\dot{q}(t) + \omega^2 q(t) = Q(t) \qquad (18b)$$

where

$$\alpha = Z^T G Z,$$

and

$$Q(t) = Z^T P(t)$$

Equation (18b), and particularly the matrix α, can now be examined to determine the conditions which will preserve the modal form

The simplest case will arise if G is proportional to K, α becomes simply the scalar $G = \alpha K$

A less restrictive form is to approximate α as a diagonal matrix simply by dropping the nondiagonal terms This is permissible (Ref 3), provided the terms of α/ω are small compared with unity (producing sharp resonances) and the natural frequencies are well separated, these are the requirements to prevent overlapping resonances

The solution of Eq (18b) is expedited by expressing this diagonal matrix as the product of diagonal matrices, as follows

$$\alpha \approx 2\beta \left(1 + \beta^2\right)^{-1/2} \omega \tag{25}$$

Substituting Eq (25) in Eq (18b) gives

$$q(t) + 2\beta\rho\, q(t) + \rho^2 \left(1 + \beta^2\right) q(t) = Q(t) \tag{26}$$

where

$$\rho = \omega \left(1 + \beta^2\right)^{-1/2}$$

is a diagonal matrix of the damped frequencies of the system

The standard solution for the ℓ'th equation of motion in Eq (26) is

$$q_\ell(t) = e^{-\beta_\ell \rho_\ell t} \left[q_{o\ell} \cos \rho_\ell t + \left(\frac{q_{o\ell}}{\rho_\ell} + \beta_\ell\, q_{o\ell} \right) \sin \rho_\ell t \right] + \frac{1}{\rho_\ell} \int_0^t Q_\ell(\tau)\, e^{-\beta_\ell \rho_\ell (t - \tau)} \sin \rho_\ell (t - \tau)\, d\tau \tag{27}$$

where

$$q_{o\ell} = \left[Z_\ell\right] K \left\{\eta_o\right\} \text{ and } q_{o\ell} = \left[Z_\ell\right] K \left\{\eta_o\right\}$$

and $\left\{\eta_o\right\}$ and $\left\{\eta_o\right\}$ represent the initial deflections and velocities, respectively

In actual applications, it will most often be the case that values of β, the decay factor, will be estimated from known characteristics of typical structures In this case Eq (17) becomes

$$P^*(t) = P(t) - KZ\left(q(t) + 2\beta\rho\, q(t)\right) \qquad (17a)$$

Eq (17a) can be substituted in Eq (19) to obtain stresses

A separation resulting in a complex mode shape can also be effected (Ref 5) for the case of a more general damping force $-G\eta(t)$, where the essential restriction on G is that it be a symmetrical matrix By this method, the rigid body modes must first be eliminated A consequence of this model is a body vibrating at its natural frequency, but with different phases, so that points on the body reach their maximum deflections at different times

V PARTITIONING

As the size and complexity of structural analysis problems increase, we must resort to partitioning Here, the engineer can use physical intuition to assist the mathematician in hard-to-manage matrix operations which result from large order matrices

Consider, for example, a structure divided into three segments (a, b, c) with three boundaries (1, 2, 3) boundary 1 between segments a and b, boundary 2 between b and c, and boundary 3 between c and a Forces $\{P_d\}$, (i e , P_1, P_2, P_3) are equal and opposite sets acting on the common boundary of the segments and are treated as redundants Fictitious reactions, $\{\gamma^s\}$, (i e , γ_a^s, γ_b^s, γ_c^s) must be supplied in the analysis of each segment to prevent rigid body motion of the segment. In addition, fictitious external forces $\{P_s\}$ (i e , P_{sa}, P_{sb}, P_{sc}) are provided at the location of and in the direction of those fictitious reactions not needed to prevent rigid body motion of the composite The fictitious reactions are given nonzero compliances

For segment "a" of the example, the deflections, defined by virtual unit (P_a, P_1, P_3, P_{sa}) loads, and the internal loads are given as follows

$$\begin{Bmatrix} \eta^a \\ \hline \eta_a^1 \\ \hline \eta_a^3 \\ \hline \eta_a^s \end{Bmatrix} = \left[\begin{array}{c|c|c|c} A_a^a & A_1^a & A_3^a & A_{sa}^a \\ \hline A_a^1 & A_{a1}^1 & A_{a3}^1 & A_{sa}^1 \\ \hline A_a^3 & A_{a1}^3 & A_{a3}^3 & A_{sa}^3 \\ \hline A_a^s & A_{a1}^s & A_{a3}^s & A_{sa}^s \end{array}\right] \begin{Bmatrix} P_a \\ \hline P_1 \\ \hline P_3 \\ \hline P_{sa} \end{Bmatrix} + \begin{bmatrix} A_h^a \\ \hline A_{ha}^1 \\ \hline A_{ha}^3 \\ \hline A_{ha}^s \end{bmatrix} \{H\} \qquad (28)$$

$$\begin{Bmatrix} \gamma_a \\ \hline \gamma_a^s \end{Bmatrix} = \left[\begin{array}{c|c|c|c} \lambda_a^a & \lambda_1^a & \lambda_3^a & \lambda_{sa}^a \\ \hline \lambda_a^s & \lambda_{a1}^s & \lambda_{a3}^s & \lambda_{sa}^s \end{array}\right] \begin{Bmatrix} P_a \\ P_1 \\ P_3 \\ P_{sa} \end{Bmatrix} + \begin{bmatrix} \lambda_h^a \\ \hline \lambda_{ha}^s \end{bmatrix} \{H\}$$

Equations (28) are simply Eqs (9) and (7) in partitioned form for segment a The deflections η^a, η_a^1, η_a^3 and η_a^s are associated with interior segmental deflections, boundary 1 deflections, boundary 3 deflections, and deflections at the location of the fictitious reaction, respectively The γ_a and γ_a^s are the real internal loads and fictitious reactions, respectively Similar expressions can be written for segments b and c

The deflections at the boundaries are as follows

$$\begin{Bmatrix} \eta_a^1 + \eta_b^1 \\ \eta_b^2 + \eta_c^2 \\ \eta_c^3 + \eta_a^3 \end{Bmatrix} = \begin{bmatrix} A_{a1}^1 + A_{b1}^1 & A_{b2}^1 & A_{a3}^1 \\ A_{b1}^2 & A_{b2}^2 + A_{c2}^2 & A_{c3}^2 \\ A_{a1}^3 & A_{c2}^3 & A_{c3}^3 + A_{a3}^3 \end{bmatrix} \begin{Bmatrix} P_1 \\ P_2 \\ P_3 \end{Bmatrix} + \begin{bmatrix} A_{sa}^1 & A_{sb}^1 & 0 \\ 0 & A_{sb}^2 & A_{sc}^2 \\ A_{sa}^3 & 0 & A_{sc}^3 \end{bmatrix} \begin{Bmatrix} P_{sa} \\ P_{sb} \\ P_{sc} \end{Bmatrix} + \begin{bmatrix} A_a^1 & A_b^1 & 0 \\ 0 & A_b^2 & A_c^2 \\ A_a^3 & 0 & A_c^3 \end{bmatrix} \begin{Bmatrix} P_a \\ P_b \\ P_c \end{Bmatrix} \begin{bmatrix} A_{ha}^1 + A_{hb}^1 \\ A_{hb}^2 + A_{ha}^2 \\ A_{hc}^3 + A_{ha}^3 \end{bmatrix} \{H\}$$

The interior deflections are

$$\begin{Bmatrix} \eta^a \\ \eta^b \\ \eta^c \end{Bmatrix} = \begin{bmatrix} A_1^a & 0 & A_3^a \\ A_1^b & A_2^b & 0 \\ 0 & A_2^c & A_3^c \end{bmatrix} \begin{Bmatrix} P_1 \\ P_2 \\ P_3 \end{Bmatrix} + \begin{bmatrix} A_{sa}^a & 0 & 0 \\ 0 & A_{sb}^b & 0 \\ 0 & 0 & A_{sc}^c \end{bmatrix} \begin{Bmatrix} P_{sa} \\ P_{sb} \\ P_{sc} \end{Bmatrix} + \begin{bmatrix} A_a^a & 0 & 0 \\ 0 & A_b^b & 0 \\ 0 & 0 & A_c^c \end{bmatrix} \begin{Bmatrix} P_a \\ P_b \\ P_c \end{Bmatrix} + \begin{bmatrix} A_h^a \\ A_h^b \\ A_h^c \end{bmatrix} \{H\}$$

The internal loads are

$$\begin{Bmatrix} \gamma_a \\ \gamma_b \\ \gamma_c \end{Bmatrix} = \begin{bmatrix} \lambda_1^a & 0 & \lambda_3^a \\ \lambda_1^b & \lambda_2^b & 0 \\ 0 & \lambda_2^c & \lambda_3^c \end{bmatrix} \begin{Bmatrix} P_1 \\ P_2 \\ P_3 \end{Bmatrix} + \begin{bmatrix} \lambda_{sa}^a & 0 & 0 \\ 0 & \lambda_{sb}^b & 0 \\ 0 & 0 & \lambda_{sc}^c \end{bmatrix} \begin{Bmatrix} P_{sa} \\ P_{sb} \\ P_{sc} \end{Bmatrix} + \begin{bmatrix} \lambda_a^a & 0 & 0 \\ 0 & \lambda_b^b & 0 \\ 0 & 0 & \lambda_c^c \end{bmatrix} \begin{Bmatrix} P_a \\ P_b \\ P_c \end{Bmatrix} + \begin{bmatrix} \lambda_h^a \\ \lambda_h^b \\ \lambda_h^c \end{bmatrix} \{H\}$$

The fictitious reactions are·

$$\begin{Bmatrix} \gamma_a^s \\ \gamma_b^s \\ \gamma_c^s \end{Bmatrix} = \begin{bmatrix} \lambda_{a1}^s & 0 & \lambda_{a3}^s \\ \lambda_{b1}^s & \lambda_{b2}^s & 0 \\ 0 & \lambda_c^s & s \end{bmatrix} \begin{Bmatrix} P_1 \\ P_2 \\ P_3 \end{Bmatrix} + \begin{bmatrix} \lambda_{sa}^s & 0 & 0 \\ 0 & \lambda_{sb}^s & 0 \\ 0 & 0 & \lambda_{sc}^s \end{bmatrix} \begin{Bmatrix} P_{sa} \\ P_{sb} \\ P_{sc} \end{Bmatrix} + \begin{bmatrix} \lambda_a^s & 0 & 0 \\ 0 & \lambda_b^s & 0 \\ 0 & 0 & \lambda_c^s \end{bmatrix} \begin{Bmatrix} P_a \\ P_b \\ P_c \end{Bmatrix} + \begin{bmatrix} \lambda_{ha}^s \\ \lambda_{hb}^s \\ \lambda_{hc}^s \end{bmatrix} \{H\}$$

The foregoing equations for boundary deflections, interior deflections, internal loads and fictitious reactions in abbreviated notation are, respectively

$$\begin{aligned}
\{\eta_d\} &= A_b \{P_d\} + A_c \{P_s\} + A_d \{P\} + A_e \{H\} \\
\{\eta\} &= A_d^T \{P_d\} + A_g \{P_s\} + A_i \{P\} + A_m \{H\} \\
\{\gamma\} &= \lambda_b \{P_d\} + \lambda_c \{P_s\} + \lambda_d \{P\} + \lambda_e \{H\} \\
\{\gamma^s\} &= \lambda_g \{P_d\} + \lambda_k \{P_s\} + \lambda_m \{P\} + \lambda_0 \{H\}
\end{aligned} \tag{29}$$

To satisfy compatibility, the relative deflections on the boundaries between adjacent segments defined by the vertical unit $\{P_d\}$ loads (redundant forces) must be set equal to zero or

$$\{\eta_d\} = \{0\} \tag{30}$$

To satisfy equilibrium at the location of the fictitious reactions, the fictitious reactions and associated fictitious loads must be made to cancel each other, that is

$$\{\gamma^s\} + \{P_s\} = \{0\} \tag{31}$$

Equations (29), (30) and (31) are now combined in one expression

$$\left\{\begin{array}{c} \eta_d = 0 \\ \hline \gamma^s + P_s = 0 \\ \hline \eta \\ \hline \gamma \end{array}\right\} = \left[\begin{array}{c|c|c|c} A_b & A_c & A_d & A_e \\ \hline \lambda_g & I + \lambda_k & \lambda_m & \lambda_0 \\ \hline A_d^T & A_g & A_i & A_m \\ \hline \lambda_b & \lambda_c & \lambda_d & \lambda_e \end{array}\right] \left\{\begin{array}{c} P_d \\ \hline P_s \\ \hline P \\ \hline H \end{array}\right\} \tag{32}$$

The deflections and internal loads in the composite supported structure can be obtained, for example, by a Gaussian reduction of the above matrix to the form

$$\left\{\begin{array}{c} \eta \\ \hline \gamma \end{array}\right\} = \left[\begin{array}{c|c|c|c} 0 & 0 & A & A_h \\ \hline 0 & 0 & \lambda & \lambda_h \end{array}\right] \left\{\begin{array}{c} P_d \\ \hline P_s \\ \hline P \\ \hline H \end{array}\right\} \tag{33}$$

The dynamic analysis may proceed from this point in the manner previously described As an alternative, the frequencies and mode shapes of the individual segments, unconstrained, can be calculated, and from them the frequencies and mode shapes of the composite structure can be calculated by the method of "dynamic influence coefficients" (Refs 6 and 7)

VI EXAMPLES

Static deflections (Ref 8) of a thick-skinned, 45° swept wing model were computed and compared against measured data (Ref 9) Figure 3 shows one of the comparisons between test deflections and the calculations by the present method

In another problem, a delta wing tested by NASA (Ref 10), both static influence coefficients and vibratory modes were calculated Agreement (Ref 11) with experiment was good in all cases A frequency comparison of the first five symmetrical modes is shown in Fig 4

Of particular interest for shell-type application is the analysis (Ref 12) of a cylindrical monocoque shell whose gridwork for the analytical model is shown in Fig 5 Agreement with known analytical results, (Ref 13) between the first eighteen axial symmetric frequencies (Table 1) is good

TABLE 1

Thin Cylindrical Shell--Symmetrical Modes

Wave Number		Frequency (cps)	
m	n	Grigolyuk	Kaufman-Hall
1	4	189	185
1	3	209	209
1	5	249	242
1	6	345	339
1	2	376	373
1	7	466	460
3	6	566	596
3	7	600	627
1	8	607	602
3	5	626	650
3	8	699	723
1	9	768	762
3	4	806	809
3	9	838	865
1	10	947	937
5	7	955	991
5	8	959	1038
3	10	1006	1040

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APPENDIX A

COMPLIANCE AND STRESS FIELDS

Deformations of elements under load (see Eq (4)) are the product of a compliance and a load For instance, the compliance of a simple tension element of Fig 1 is ℓ/aE where ℓ is its length, a its cross-sectional area and E its modulus of elasticity The compliances associated with a simple beam are slightly more complicated Consider two two-digit bending elements (Fig 1), one on either end of the beam Let M^1 and M^2 denote their internal loads and θ^1 and θ^2 be their corresponding angular deformations The symmetrical compliance submatrix (E_o) for this system, neglecting shear deformation, is obtained by the following relationship

$$\begin{Bmatrix} \theta^1 \\ \theta^2 \end{Bmatrix} = \frac{\ell}{EI} \begin{bmatrix} \frac{1}{3} & \frac{1}{6} \\ \frac{1}{6} & \frac{1}{3} \end{bmatrix} \begin{Bmatrix} M^1 \\ M^2 \end{Bmatrix} = E_o \begin{Bmatrix} M^1 \\ M^2 \end{Bmatrix} \tag{1}$$

where I is the moment of inertia of the beam cross section

In any network analysis, the proper representation of elastic properties is of utmost importance For example, the behavior of a skew plate is contained mainly in the peculiar and strongly coupled properties of its skew elements The development of a compliance matrix for structures entails two main considerations (1) establishing properties associated with a particular type of stress field, and (2) assigning these properties to the discrete elements of the network

Two types of stress fields are shown in Fig 6 The parallelogram field is an adaptation of the system ordinarily used for rectangular panels For irregular structures, the triangular field is simpler and more versatile An analogue between deformations and deflections makes the compliance matrices for these stress fields rather easy to derive For the parallelogram field, consider the parallelogram as a structure, the skew stresses $\begin{Bmatrix} \sigma_1 \\ \sigma_2 \\ \tau_{12} \end{Bmatrix}$ as external forces, the skew strains $\begin{Bmatrix} \epsilon_1 \\ \epsilon_2 \\ \gamma_{12} \end{Bmatrix}$ as deflections, the orthogonal stresses $\begin{Bmatrix} \sigma_a \\ \sigma_b \\ \tau_{ab} \end{Bmatrix}$ as internal element

loads, orthogonal strains $\begin{Bmatrix} \epsilon_a \\ \epsilon_b \\ \gamma_{ab} \end{Bmatrix}$ as deformations in the elements and E_o the compliance matrix for orthogonal stresses The deformations in the elements in terms of the internal loads are

$$\begin{Bmatrix} \epsilon_a \\ \epsilon_b \\ \gamma_{ab} \end{Bmatrix} = \frac{1}{E} \begin{bmatrix} 1 & -\mu & 0 \\ -\mu & 1 & 0 \\ 0 & 0 & 2+2\mu \end{bmatrix} \begin{Bmatrix} \sigma_a \\ \sigma_b \\ \tau_{ab} \end{Bmatrix} = E_o \begin{Bmatrix} \sigma_a \\ \sigma_b \\ \tau_{ab} \end{Bmatrix} \tag{2}$$

where μ is Poisson's ratio for isotropic material The equilibrium relationship between the internal loads and external forces is

$$\begin{Bmatrix} \sigma_a \\ \sigma_b \\ \tau_{ab} \end{Bmatrix} = \begin{bmatrix} 1 & \cos^2 \Omega & 2 \cot \Omega \\ 0 & \sin^2 \Omega & 0 \\ 0 & \sin \Omega \cos \Omega & 1 \end{bmatrix} \begin{Bmatrix} \sigma_1 \\ \sigma_2 \\ \tau_{12} \end{Bmatrix} = S_o \begin{Bmatrix} \sigma_1 \\ \sigma_2 \\ \tau_{12} \end{Bmatrix} \tag{3}$$

The deflections (skew strains) measured by unit (virtual) external forces (skew stresses) are

$$\begin{Bmatrix} \epsilon_1 \\ \epsilon_2 \\ \gamma_{12} \end{Bmatrix} = S_o^T \begin{Bmatrix} \epsilon_a \\ \epsilon_b \\ \gamma_{ab} \end{Bmatrix} = S_o^T E_o S_o \begin{Bmatrix} \sigma_1 \\ \sigma_2 \\ \tau_{12} \end{Bmatrix} \tag{4}$$

where

$$S_o^T E_o S_o = \frac{1}{E} \begin{bmatrix} 1 & \cos^2 \Omega - \mu \sin^2 \Omega & 2 \cot \Omega \\ \cos^2 \Omega - \mu \sin^2 \Omega & 1 & 2 \cot \Omega \\ 2 \cot \Omega & 2 \cot \Omega & 4 \cot^2 \Omega + 2(1+\mu) \end{bmatrix}$$

is the compliance matrix for the skew stresses

For the triangular network, the relationship between internal loads and external forces $\begin{Bmatrix} \sigma_1 \\ \sigma_2 \\ \sigma_3 \end{Bmatrix}$ is

$$\begin{Bmatrix} \sigma_a \\ \sigma_b \\ \tau_{ab} \end{Bmatrix} = \begin{bmatrix} \cos^2 \Omega_1 & \cos^2 \Omega_2 & \cos^2 \Omega_3 \\ \sin^2 \Omega_1 & \sin^2 \Omega_2 & \sin^2 \Omega_3 \\ \sin \Omega_1 \cos \Omega_1 & \sin \Omega_2 \cos \Omega_2 & \sin \Omega_3 \cos \Omega_3 \end{bmatrix} \begin{Bmatrix} \sigma_1 \\ \sigma_2 \\ \sigma_3 \end{Bmatrix}$$

$$= S_o \begin{Bmatrix} \sigma_1 \\ \sigma_2 \\ \sigma_3 \end{Bmatrix} \tag{5}$$

The deflections $\begin{Bmatrix} \epsilon_1 \\ \epsilon_2 \\ \epsilon_3 \end{Bmatrix}$ measured by unit (virtual) external forces are

$$\begin{Bmatrix} \epsilon_1 \\ \epsilon_2 \\ \epsilon_3 \end{Bmatrix} = S_o^T \begin{Bmatrix} \epsilon_a \\ \epsilon_b \\ \gamma_{ab} \end{Bmatrix} = S_o^T E_o S_o \begin{Bmatrix} \sigma_1 \\ \sigma_2 \\ \sigma_3 \end{Bmatrix} \tag{6}$$

where the compliance matrix $S_o^T E_o S_o$ for the triangular stresses is

$$S_o^T E_o S_o = \frac{1}{E} \begin{bmatrix} 1 & \beta_{12} & \beta_{31} \\ \beta_{12} & 1 & \beta_{23} \\ \beta_{31} & \beta_{23} & 1 \end{bmatrix}$$

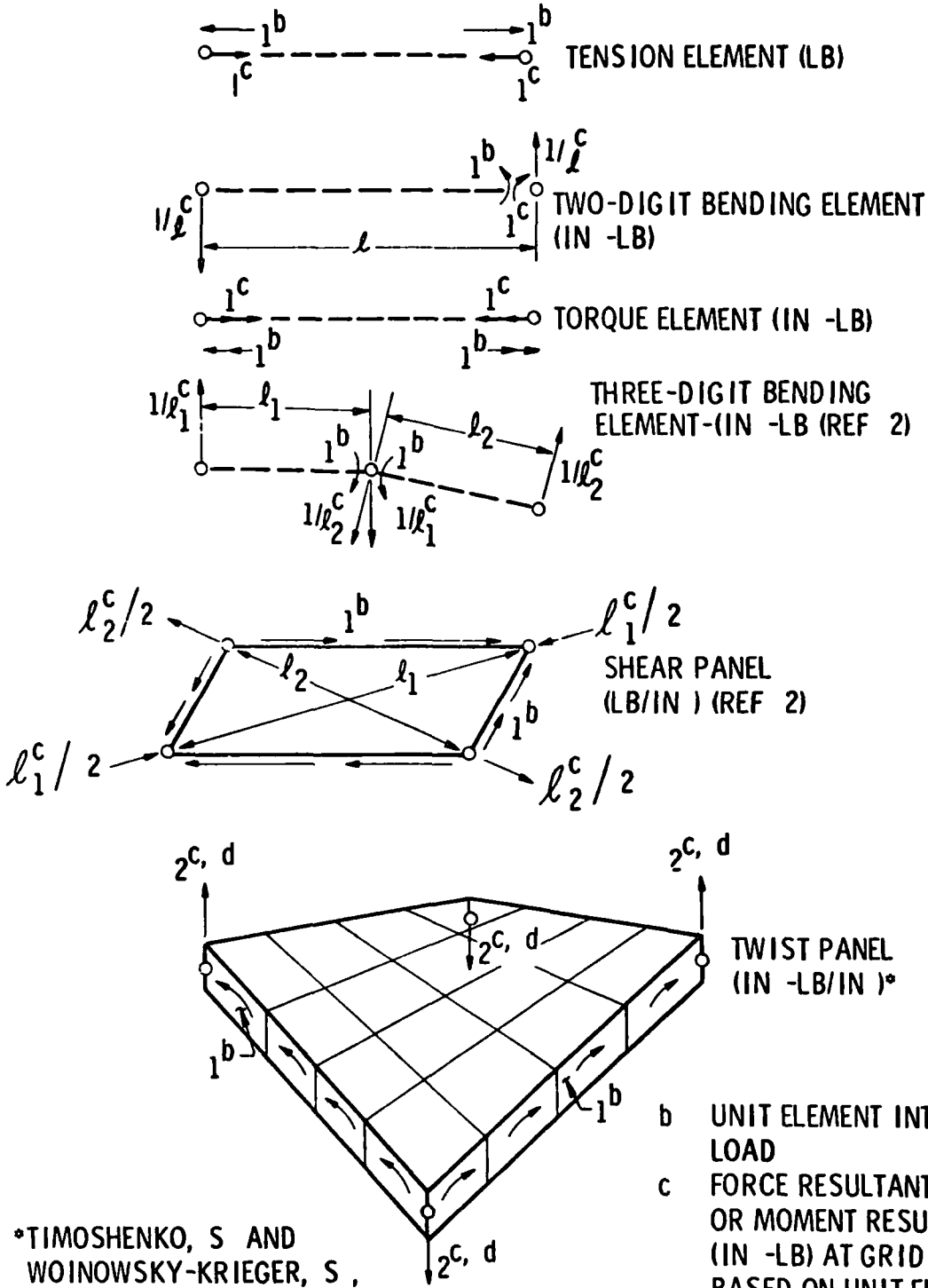
and $\beta_{ij} = \cos^2(\Omega_i - \Omega_j) - \mu \sin^2(\Omega_i - \Omega_j)$

The stress fields for the parallelogram and triangle are represented by the discrete elements of Fig 1 The compliances for these discrete elements are found by virtual work, integrating the proper component in the compliance matrix $S_o^T E_o S_o$ over the volume of an element or the intersecting volume of two coupled elements

With a little manipulation in one or two instances to facilitate computation, the compliances for all types of elements considered come out as listed in Fig 7 (for parallelogram network) and Fig 8 (for triangular network)

APPENDIX B

ILLUSTRATIONS


TENSION ELEMENT (LB)
TWO-DIGIT BENDING ELEMENT (IN -LB)
TORQUE ELEMENT (IN -LB)
THREE-DIGIT BENDING ELEMENT-(IN -LB (REF 2)
SHEAR PANEL (LB/IN) (REF 2)
TWIST PANEL (IN -LB/IN)*

*TIMOSHENKO, S AND WOINOWSKY-KRIEGER, S , "THEORY OF PLATES AND SHELLS," P 45, McGRAW-HILL

b UNIT ELEMENT INTERNAL LOAD

c FORCE RESULTANT (LB) OR MOMENT RESULTANT (IN -LB) AT GRID POINTS BASED ON UNIT ELEMENT INTERNAL LOAD

d FORCE RESULTANT OF 2 FOR PARALLELOGRAMS ONLY

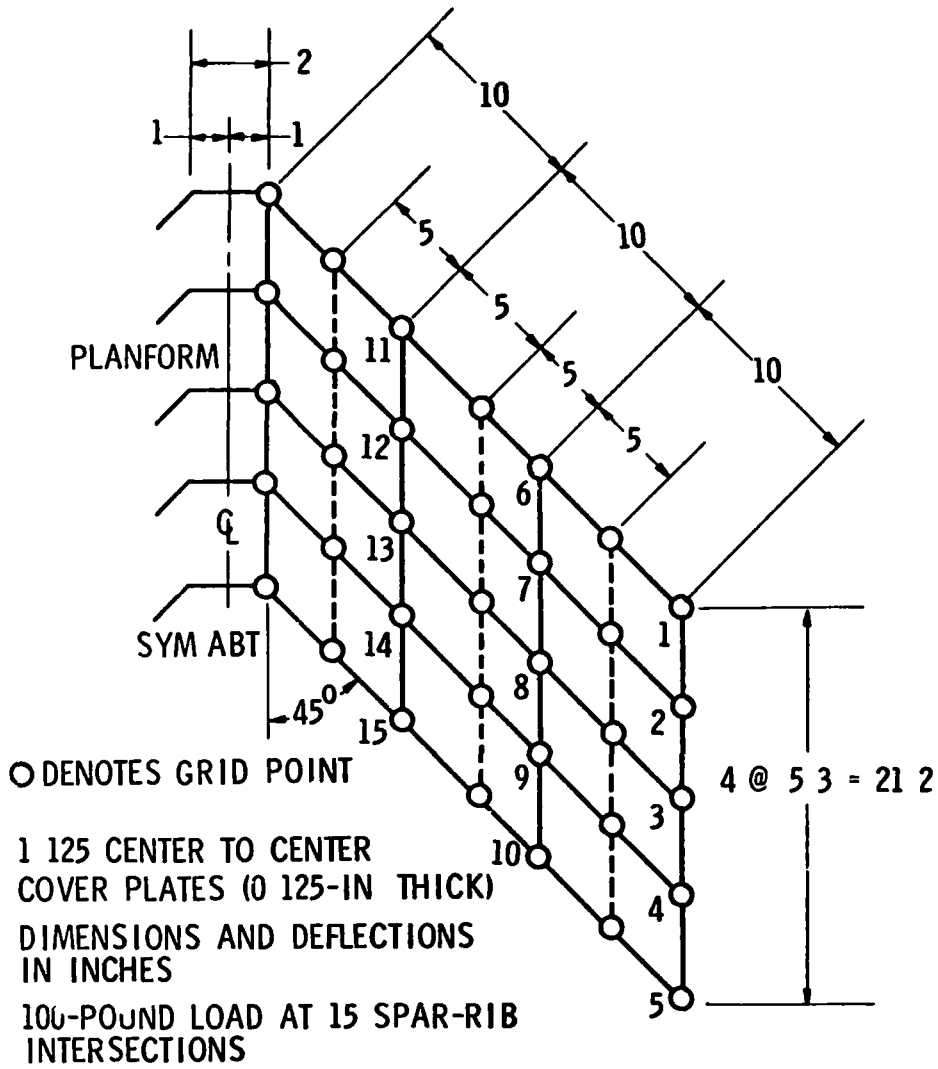
FIG 1 STRUCTURAL ELEMENTS

$$D\{\xi\} = \begin{bmatrix} a_r & b_r & c_r & y^I c_r & z^I a_r & x^I b_r \\ & & & -z^I b_r & -x^I c_r & -y^I a_r \\ a_s & b_s & c_s & y^I c_s & z^I a_s & x^I b_s \\ & & & -z^I b_s & -x^I c_s & -y^I a_s \\ a_t & b_t & c_t & y^I c_t & z^I a_t & x^I b_t \\ & & & -z^I b_t & -x^I c_t & -y^I a_t \\ 0 & 0 & 0 & a_r & b_r & c_r \\ 0 & 0 & 0 & a_s & b_s & c_s \\ 0 & 0 & 0 & a_t & b_t & c_t \end{bmatrix} \begin{Bmatrix} a^x \\ a^y \\ a^z \\ \alpha x \\ \alpha y \\ \alpha z \end{Bmatrix}$$

$$K = \begin{bmatrix} M^I & 0 & 0 & 0 & H_t^I & -H_s^I \\ 0 & M^I & 0 & -H_t^I & 0 & H_r^I \\ 0 & 0 & M^I & H_s^I & -H_r^I & 0 \\ 0 & -H_t^I & H_s^I & I_{rr}^I & -I_{rs}^I & -I_{tr}^I \\ H_t^I & 0 & -H_r^I & -I_{rs}^I & I_{ss}^I & -I_{st}^I \\ -H_s^I & H_r^I & 0 & -I_{tr}^I & -I_{st}^I & I_{tt}^I \end{bmatrix}$$

MAIN DIAGONAL OF MASS MATRIX

FIG 2 MASS AND RELATED TRANSFORMATION MATRIXES



SPAR-RIB INTER-SECTION	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
COMPUTED DEFLEC-TIONS	0 4544	0 5283	0 6093	0 6955	0 7828	0 2263	0 2840	0 3436	0 4110	0 4877	0 0638	0 0949	0 1234	0 1563	0 2029
MEASURED DEFLEC-TIONS	0 4288	0 5109	0 6015	0 6946	0 7970	0 2090	0 2774	0 3382	0 4069	0 4972	0 0709	0 1003	0 1307	0 1626	0 2093

FIG 3 COMPARISON OF ANALYTICAL WITH TEST DEFLECTIONS--45-DEG SWEPT WING MODEL

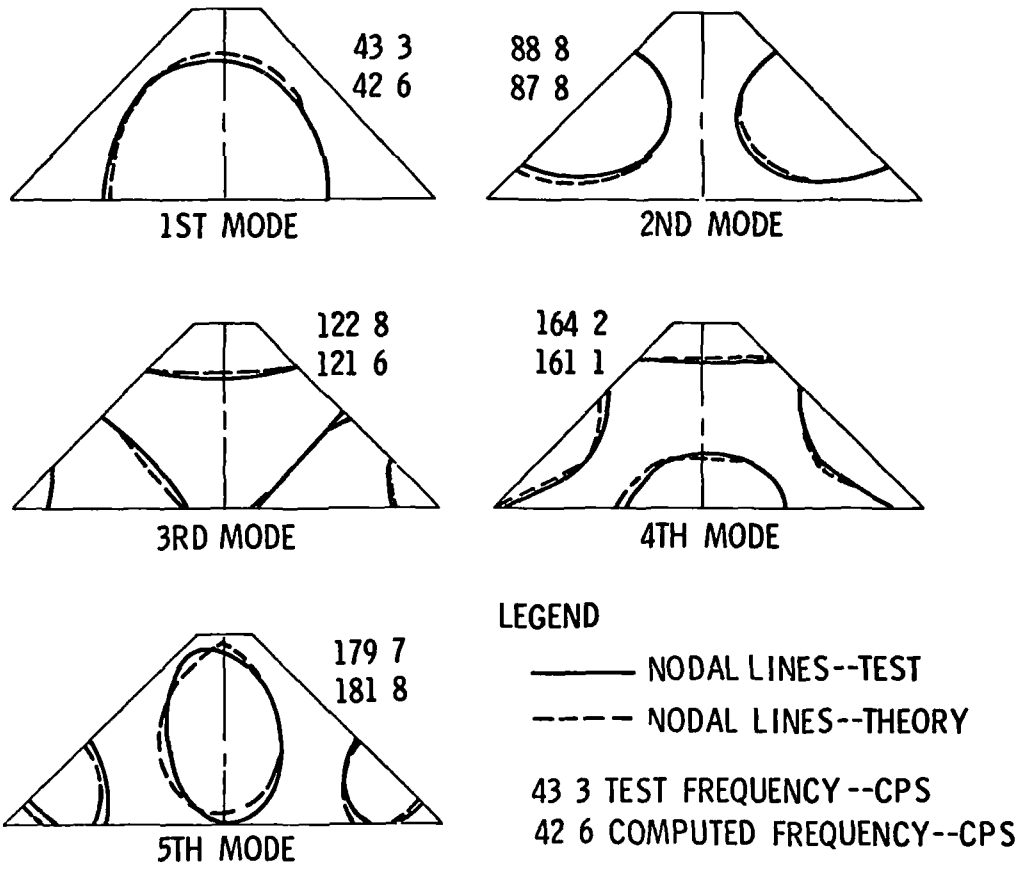


FIG 4 COMPARISON OF TEST WITH THEORY SYMMETRICAL MODES--
45-DEG DELTA WING

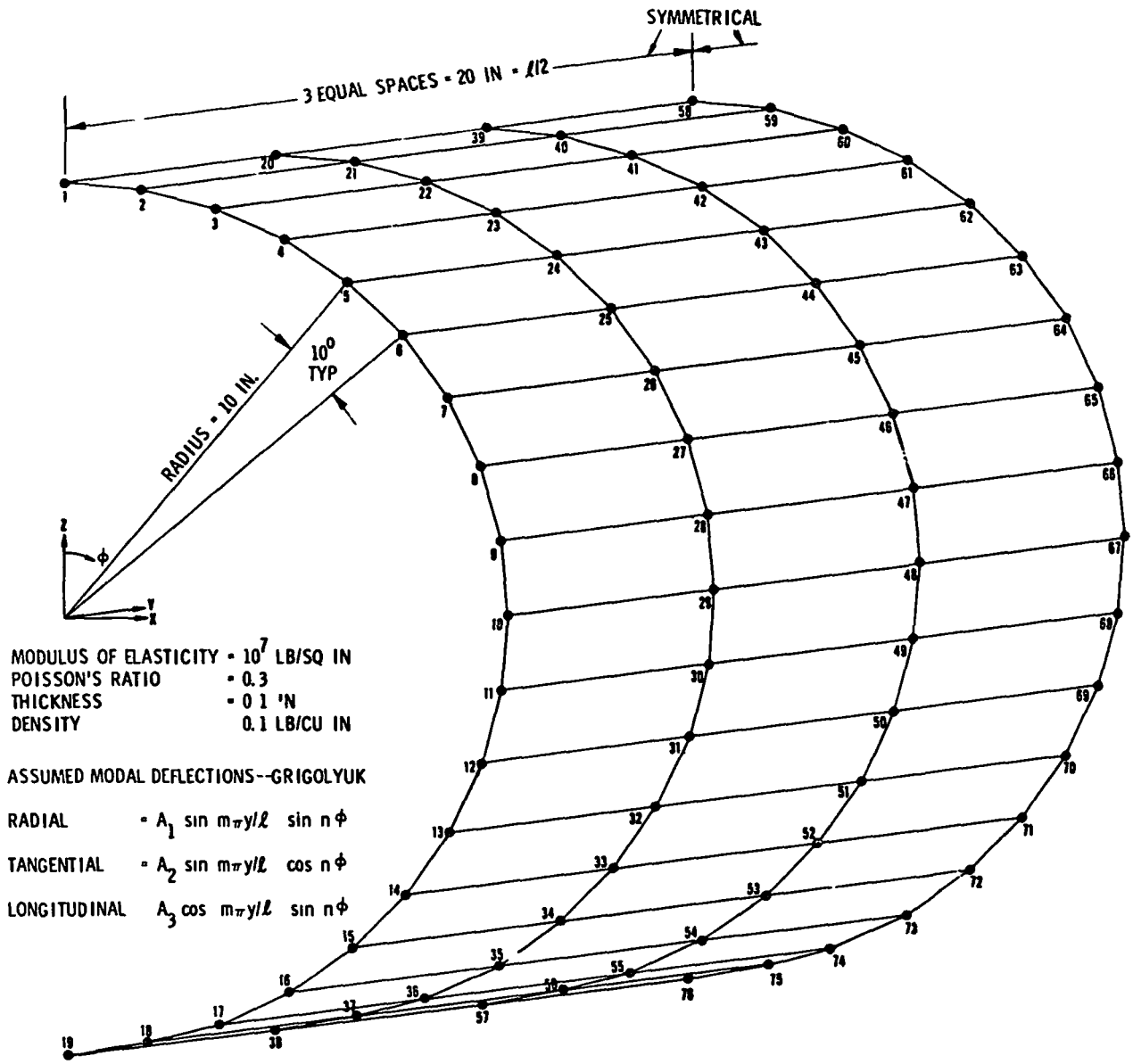
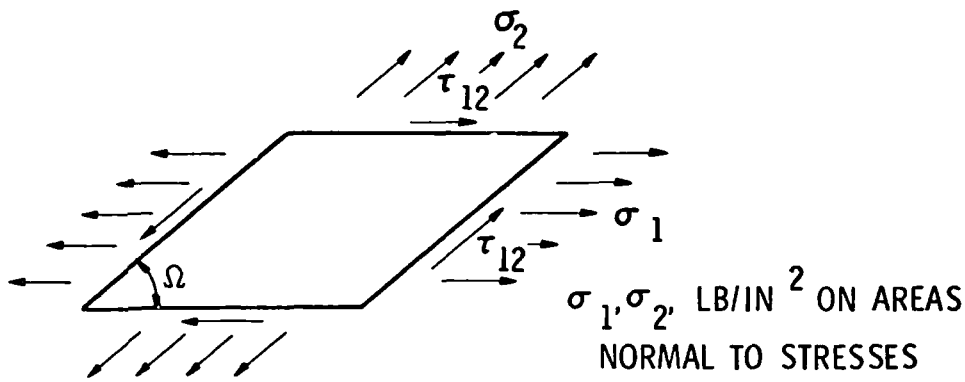
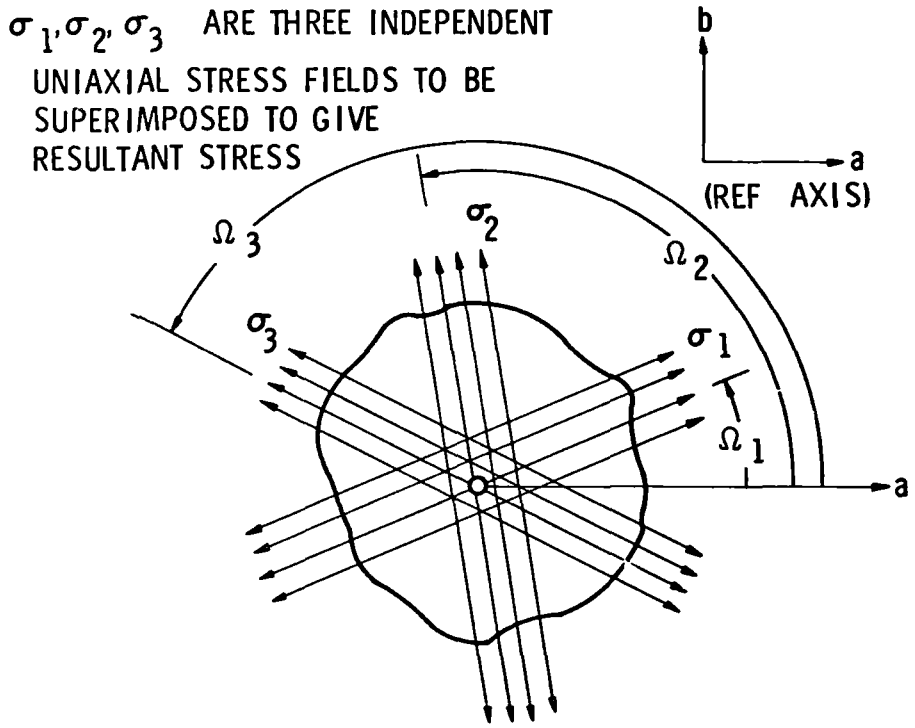

SYMMETRICAL
3 EQUAL SPACES = 20 IN = ℓ/2
RADIUS = 10 IN.
10° TYP
MODULUS OF ELASTICITY = 10^7 LB/SQ IN
POISSON'S RATIO = 0.3
THICKNESS = 0 1 'N
DENSITY 0.1 LB/CU IN
ASSUMED MODAL DEFLECTIONS--GRIGOLYUK
RADIAL = A1 sin mπy/ℓ sin nϕ
TANGENTIAL = A2 sin mπy/ℓ cos nϕ
LONGITUDINAL A3 cos mπy/ℓ sin nϕ

FIG 5 THIN CYLINDRICAL SHELL

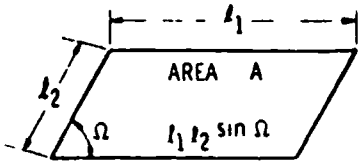


SKEW (PARALLELOGRAM) FIELD



TRIANGULAR FIELD

FIG 6 STRESS FIELDS



TYPICAL PANEL

h • THICKNESS

ℓ ℓ_1 OR ℓ_2 AS APPLICABLE

TENSION ELEMENT

3-DIGIT BENDING ELEMENT

2 DIGIT BENDING ELEMENT

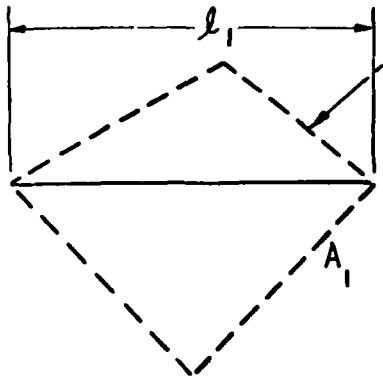
SHEAR OR TWIST PANEL

ELEMENT CODE

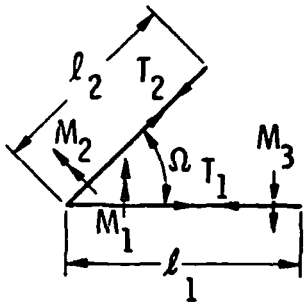
			FOR EDGE MEMBER
DIAGONAL		$\frac{1}{Eh}\frac{\ell^2}{A}$	$\frac{1}{Eh}\frac{2\ell^2}{A}$
		$\frac{12}{Eh^3}\frac{2\ell^2}{3A}$	$\frac{12}{Eh^3}\frac{4\ell^2}{3A}$
		$\frac{12}{Eh^3}\frac{\ell^2}{3A}$	$\frac{12}{Eh^3}\frac{2\ell^2}{3A}$
	SHEAR	$\frac{1}{Eh} A\left[4\cot^2\Omega + 2(1+\mu)\right]$	
	TWIST	$\frac{12}{Eh^3} A\left[4\cot^2\Omega + 2(1+\mu)\right]$	
COUPLED		$\frac{\beta}{4Eh\sin\Omega}$	$\frac{\beta}{2Eh\sin\Omega}$ edge $\frac{\beta}{Eh\sin\Omega}$ corner
		$\frac{12}{Eh^3}\frac{\cos^2\Omega - \mu\sin^2\Omega}{\sin\Omega}$	
		$\frac{12\beta}{2Eh^3\sin\Omega}$	$\frac{12\beta}{Eh^3\sin\Omega}$
		$\frac{12\beta}{4Eh^3\sin\Omega}$	$\frac{12\beta}{2Eh^3\sin\Omega}$ edge $\frac{12\beta}{Eh^3\sin\Omega}$ corner
	SHEAR	$\frac{1}{Eh}\ell\cot\Omega$	$\frac{1}{Eh}2\ell\cot\Omega$
	TWIST	$\frac{12}{Eh^3}\frac{\ell\cot\Omega}{2}$	$\frac{12}{Eh^3}\ell\cot\Omega$
	TWIST	$\frac{12}{Eh^3}\frac{\ell\cot\Omega}{2}$	$\frac{12}{Eh^3}\ell\cot\Omega$
		$\frac{12}{Eh^3}\frac{\ell^2}{6A}$	EDGE MEMBER $\frac{12}{Eh^3}\frac{\ell^2}{3A}$
		LINEAL COUPLING FOR BENDING ELEMENTS	

$\beta = \cos^2\Omega - \mu\sin^2\Omega$

FIG. 7 COMPLIANCE FOR PARALLELOGRAM NETWORK



DIAGONAL COMPLIANCE



TENSION ELEMENT $\frac{1}{Eh}\ \frac{\ell_1^2}{A_1}$

2-DIGIT BENDING ELEMENT $\frac{12}{Eh^3}\ \frac{\ell_1^2}{3A_1}$

COUPLED COMPLIANCE

TENSION ELEMENT (T_1 with T_2) $\frac{1}{Eh}\ (\cos^2\Omega - \mu\sin^2\Omega)\ \frac{\ell_1^2 \ell_2^2 \sin\Omega}{2A_1 A_2}$

2-DIGIT BENDING ELEMENT (M_1 with M_2) $\frac{12}{Eh^3}\ (\cos^2\Omega - \mu\sin^2\Omega)\ \frac{\ell_1^2 \ell_2^2 \sin\Omega}{2A_1 A_2}$

2-DIGIT BENDING ELEMENT (M_1 with M_3) $\frac{12}{Eh^2}\ \frac{\ell_1^2}{6A_1}$

A_1 AND A_2 ARE AREAS CORRESPONDING TO ℓ_1 and ℓ_2

FOR INTERIOR OF A NETWORK OF CONGRUENT TRIANGLES

$$\frac{\ell_1^2 \ell_2^2 \sin\Omega}{2A_1 A_2} = \frac{1}{2\sin\Omega}$$

FIG 8 COMPLIANCES FOR TRIANGULAR NETWORK

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APPENDIX C

OPERATING MANUAL FOR SEAL SHELL 2 COMPUTER PROGRAM

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SEAL SHELL 2 is a digital computer program that determines stresses, loads and deflections of a thick shell of revolution with applied axisymmetric pressures, temperatures and distributed loads This program was developed at Westinghouse Bettis by C M Friedrich under contract with the Atomic Energy Commission and is an improved and extended version of SEAL SHELL 1 The program achieves its particular value for handling thermal loads as well as the common static force systems, and secondly, thick shell effects are taken into consideration by means of including a parabolic shear distribution through the thickness The thermal gradient capacity includes both meridional and thickness gradients The gradients through the shell thickness are introduced by temperature inputs at five locations, three internal points and the two surfaces Thus, most any temperature profile may be included with extreme accuracy

The generating curve of the shell may be subdivided into segments numbering up to 100 and will handle midsurface shifts between them Each finite segment may have its own modulus, thickness, height and thermal expansion coefficient

The method of solution is the establishment of a stiffness matrix from the strain energy by means of the principle of virtual work As previously stated, the strain energy from normal and shear stresses are included for the thick wall contribution, thus expanding the solution beyond Love's first approximation

The program output includes normal, shear, circumferential and meridional stresses, deflections and slopes and includes the stress intensities based upon both Tresca and von Mises (particularly useful for fatigue analysis) The outputs are listed for thermal and static loading cases separately and superimposed

In addition, the printout includes the input data and the flexibility matrix of end loads

Some applications of SEAL SHELL 2 are

(1) Pressure vessel design

(2) Nozzle design

(3) Bellows

(4) Seal welds

(5) Circular plates

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Two appendices are included within this report The first presents an example problem and the second provides the derivation of the shell equations developed for SEAL SHELL

A NOMENCLATURE

a	{Position K-1 on segment K {Position K_a on group of Segments K_a to K_b
_a	Value of _ at position a
_ab	Change in value of _ from a to b (_ab) = (_b) - (_a)
b	{Position K on Segment K {Position K_b on group of Segments K_a to K_b
_b	Value of _ at Position b
_c	Value of _ at center of ellipse
d_	Infinitesimal change in _ produced by the coordinate changes dX, dθ and/or dY
D_{mo}	Rotation at 0, $+\curvearrowright_{\circ}$ $D_{mo} = (D_1)_5$ in Fig 8
D_{mn}	Rotation at n, $+\curvearrowright_{\circ}$ $D_{mn} = (D_n)_7$ in Fig. 8
D_{ro}	Radial deflection at 0, $+\leftarrow_{\circ}$ $D_{ro} = (D_1)_4$ in Fig 8
D_{rn}	Radial deflection at n, $+\rightarrow_{\circ}$ $D_{rn} = (D_n)_6$ in Fig 8
D_{zn}	Axial deflection of shell, $\downarrow_{\circ}$ $D_{zn} = \sum_{1}^{n} k(D_k)_3$ in Fig 8
E_s	Shear modulus of elasticity
E_t	Tensile modulus of elasticity
F_{mo}	Bending moment at 0 (in -lb) $+\curvearrowright_{\circ}$ $F_{mo} = (F_1)_5$
F_{mn}	Bending moment at n (in -lb) $+\curvearrowleft_{\circ}$ $F_{mn} = (F_n)_7$
F_{ro}	Radial force at 0 (lb) $+\leftarrow_{\circ}$ $F_{rs} = (F_1)_4$

F_{rn} Radial force at n (lb) $+\rightarrow$ $F_{rn} = (F_n)_6$

F_{zn} Axial force at n (lb) $+\downarrow$ $F_{zn} = (F_n)_3$

G_ Value of F_ if K_ = 1

Value of D_ if K_ = 0

H Thickness (in)

K Position along X axis, 0 to n

K Segment along X axis, 1 to n

Segment K is between Positions K-1 and K

Position K is between Segments K and K+1

_k Value of _ at Position K or on Segment K

N Number of segments, 2 to 100 Last position

_n Value of _ at Position N or on Segment N

P_i Inside pressure (psi)

P_o Outside pressure (psi)

Q_x Shear force per unit length of circumference (lb/in)

R Radius from axis of revolution for middle surface

R_y Radius at Distance Y from middle surface

S_{ave} Stress at center of Mohr' s circle

S_e Sign of curvature in a segment

$$S_e = \begin{Bmatrix} +1 \\ 0 \\ -1 \end{Bmatrix} \text{ if } \phi'(x) \begin{Bmatrix} > \\ = \\ < \end{Bmatrix} 0$$

S_i Stress at inside surface, Y = H/2

S_{max} Maximum stress on von Mises' criteria

S_o Stress at outside surface, Y = - H/2

S_{rad}	Radius of Mohr's circle
S_x	Meridional stress
S_y	Thickness stress
S_O	Hoop stress
T	Temperature (°F)
T(Y)	T at Distance Y from middle surface
U	Inward displacement at Y relative to middle surface
V	Meridional displacement of the middle surface
W	Inward displacement of the middle surface
$(W_r)_k$	Radial load external to Segment K at Position K, +→
$(W_m)_k$	Bending load external to Segment K at Position k, +↶
$(W_z)_k$	Axial load external to Segment K at Position K, +↓
X	Meridional coordinate of middle surface
Y	Inward coordinate from middle surface
Z	Axial coordinate of middle surface
α	Coefficient of linear thermal expansion((in /in)/°F)
Y_{xy}	Shear strain for Directions X and Y
ν	Poisson's ratio, $0 < \nu < 1/2$
T_{xy}	Shear stress for Directions X and Y
T_{max}	Maximum shear strain
ϕ	Angle of tilt of middle surface of shell (see Fig C-2)

B MODEL DEVELOPMENT AND GEOMETRY

The axisymmetric shell of revolution is geometrically described by its intersection with a meridional plane passing through the axis as shown in Fig C-1. The intersection surface is determined by the thickness and by the coordinates of the middle surface Let

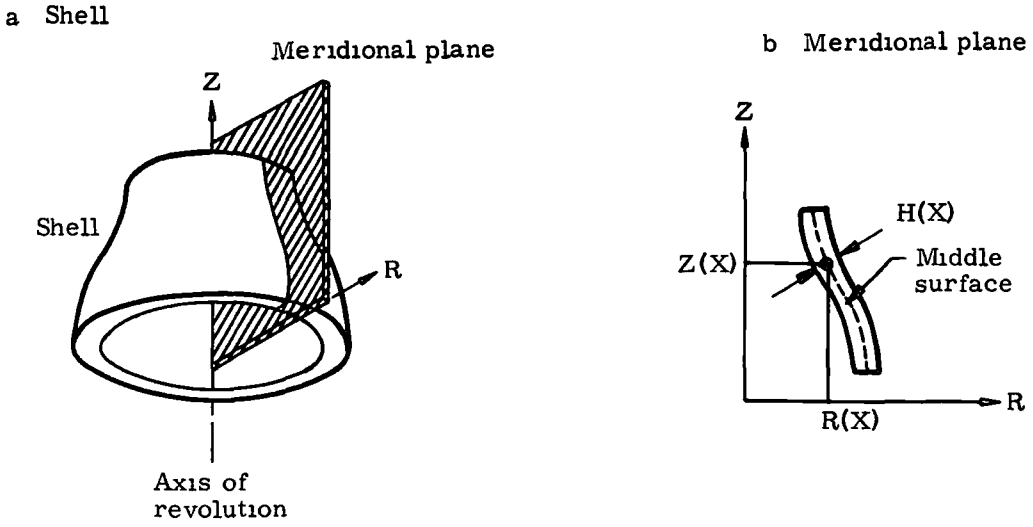


Fig C-1 Meridional Plane in Axisymmetric Shell

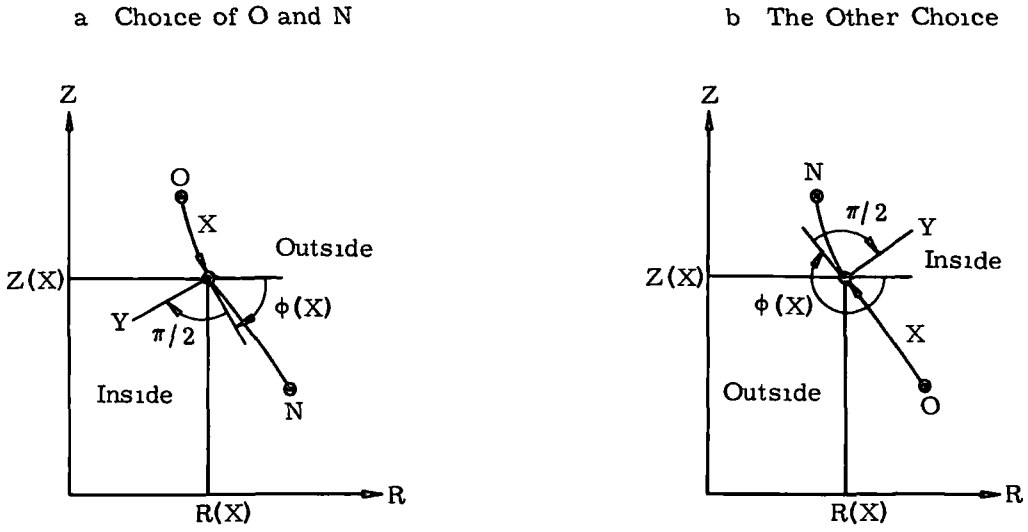


Fig C-2 Curvilinear Coordinates of Middle Surface

X = position along the meridional line of the middle surface

H = H(X) = thickness at X

R = R(X) = radius of the middle surface, + →

Z = Z(X) = elevation of the middle surface, + ↑

The intersecting line of the middle surface in the RZ plane has two end points, 0 and N Instead of the cylindrical coordinates R and Z, curvilinear coordinates X and Y may be used, where

X = distance along the line from 0 toward N

Y = normal distance from the middle surface, $\pi/2$ radians from the local direction of the X axis

1 Shell Cannot Be Closed at Either End

To ensure an insignificant error in the results, it is recommended that a small hole (R = 0 001 in) be assumed through the shell at the axis of symmetry This method will closely approximate the condition of zero slope, tangential displacement, rotation and shear which normally hold at a closed end The details of the shell are given in a profile drawing of the lines of the inner surface, the middle plane and the outer surface in the meridional plane (Fig C-1) The profile is divided into two or more incremental lengths called segments The maximum number of segments depends on the capacity of the machine in use The first segment starts at the initial point 0(R_o, Z_o) This is not the origin of the R-Z axis The last segment is N (Fig C-2) All other points are at the end of each segment and bear the segment number For simple parts the number of segments should be between 2 and 10 Near discontinuities, shorter segments are needed to give satisfactory results Segments as small as one-tenth the thickness can be used In a cylinder with discontinuities the segment length should be less than 0 5 $\sqrt{RH}$

Typical model profiles are shown in Fig C-3 where the selection of origin, terminal points and curve shapes are presented It should be noticed that in many applications, R_o and/or R_n are 0 001 inch (must not be zero) S_e is the curvature designation

In order to consider the variation of thickness along the meridian profile, it is recommended that the inner and outer surfaces are sketched to scale to aid in the decision of choice of segments Variations in the curvature and the method of load input give rise to special

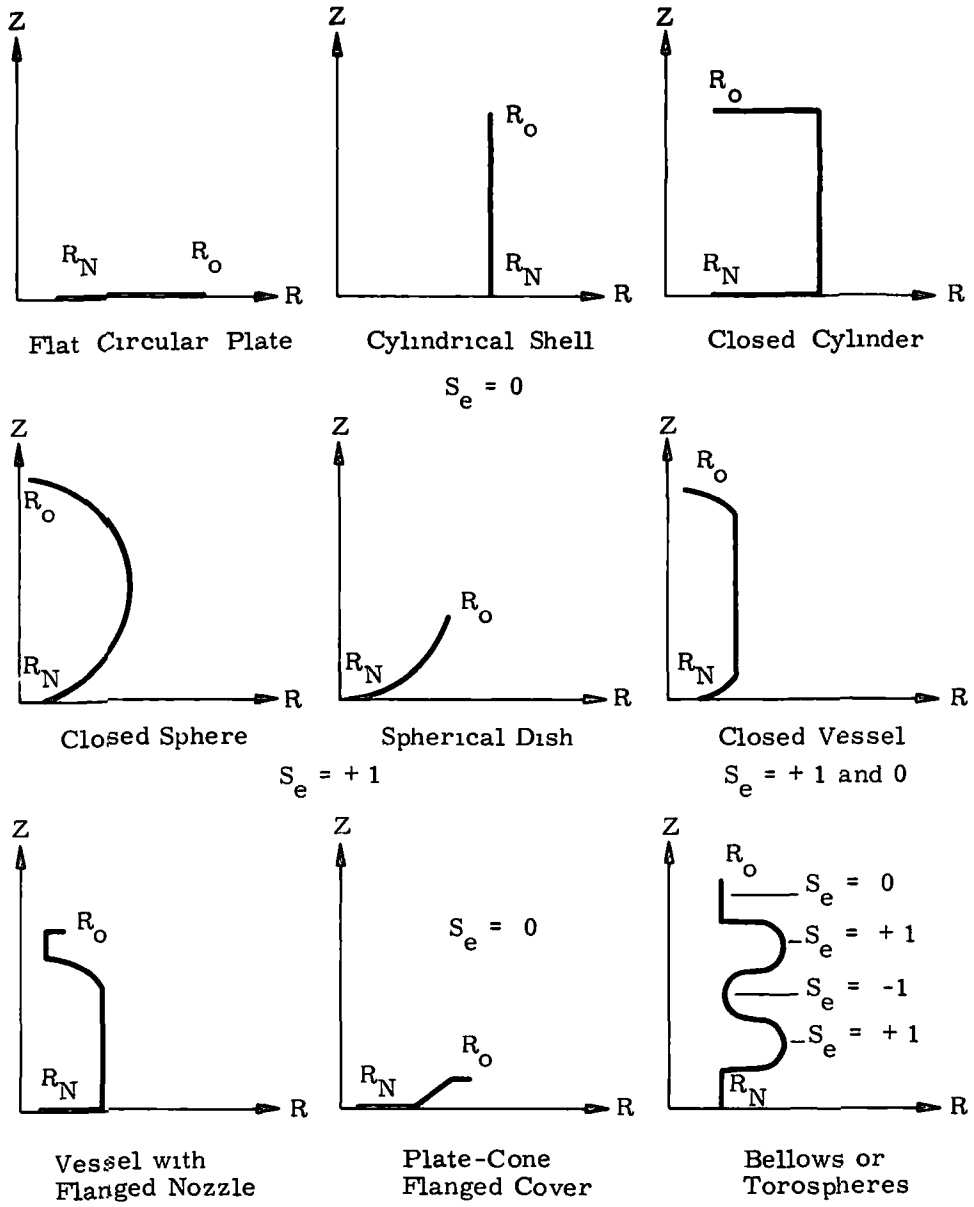
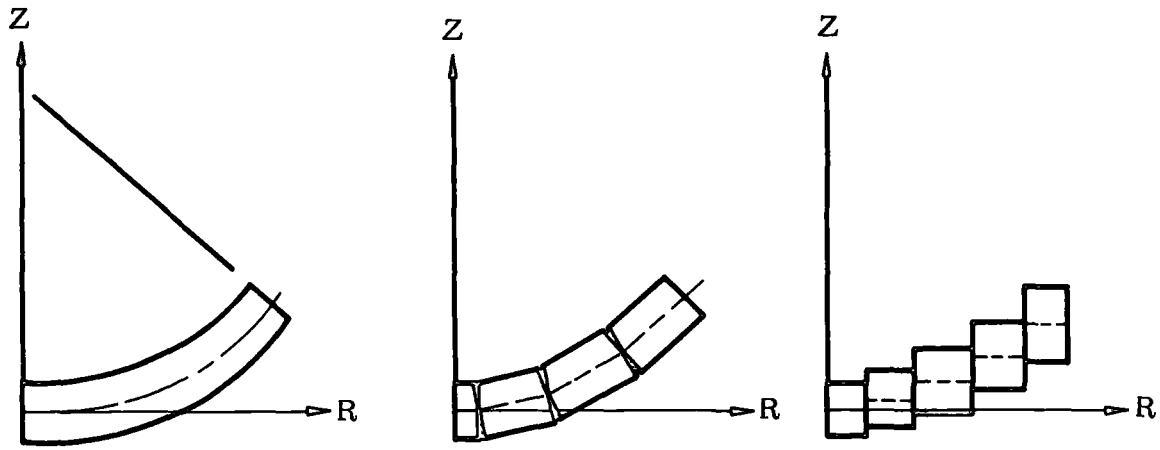


Fig C-3 Typical Model Profiles

considerations for choosing the middle plane. In any case, the middle plane must always be halfway between the segmented model surfaces An additional consideration is the fact that the program allows middle plane shifts to accommodate thickness and/or curvature changes A segment of zero thickness is used to accomplish this task (A segment of zero thickness is assumed to be perfectly rigid) A common application of this shift capability is illustrated in Fig C-4 where a variation in slope and curvature is the primary consideration Figure 4 also illustrates the possible geometric approaches that may be taken



Curved Middle Plane	Connected Cones	Rings with Shifts
Radial ends of segments	Overlapping contour of segments	Contour with increments
Exact shell contour, exact pressure surface area	Surface area approximate	Exact pressure and surface area for axial loading

Fig C-4 Possible Geometric Approaches

Important Note

For the case where the center of curvature is on the axis, the ratio of outer-to-inner meridional radius should not exceed 1 25 for 1% error of stresses A ratio of 1 3 is within 5% error and a ratio of 1 4 can have 50% error The further the center of curvature is from the axis, the smaller the error becomes When positive and negative curvature come together, the error increases and the radius ratio should be less than 1 3 for centers removed from the axis

C PROGRAM INPUT

This section of the report presents the detailed description of all input data cards necessary to obtain a correct program execution The input deck begins with an accounting card and always ends with a blank card Table 1 presents a detailed layout of all program cards which should be carefully and continually used as reference to correctly fill out the FORTRAN programming form Note that the proper card column allocations are included It is important to remember that each input entry should be entered from the right side of the field since the FORTRAN system assumes zeros in the field where no entry is incorporated

1 Title Card

The title card may contain any title or description as long as the space from Column 2 through Column 60 is not exceeded In addition, 110 + 0 and the number of comment cards desired from 0 to 20 are required (see Table 1).

2 Comment Cards

I = number of comment cards from 1 to N_c If no comment cards are required by the user, zero is entered for N_c on the title card and no comment cards will be employed The comment card information is left to the discretion of the user The only restrictions are the limit of 20 cards and the space between Columns 2 and 60 may not be exceeded per card

3 101 + 0 and 102 + 0 Cards

These two cards are utilized to enter boundary condition deflections and forces

N = number of segments in model (restricted from 2 to 100)

$$K_{\_} = \begin{cases} 0 \text{ if deflection } D_{\_} \text{ is given} \\ 1 \text{ if force } F_{\_} \text{ is given} \end{cases}$$

$G_{\_}$ = magnitude of $D_{\_}$ or $F_{\_}$

Refer to the Nomenclature in Section A of this Appendix to incorporate the correct sign convention of the particular deflections and forces Note that all deflections are in inches, forces in pounds and moments entered in inch-pounds

TABLE 1 INPUT CARDS FOR SEAL-SHELL-2

ACCOUNTING CARD

*	8 TO 10	16 TO 20	25 TO 30	33 TO 46	51 TO 80
	FOR	SN200	02-104	CHARGE NO	NAME & PHONE EXT

PROBLEM CARDS

1	2 TO 10	11 TO 20	21 TO 30	31	32 TO 40	41 TO 50	51 TO 60	61 TO 70	71	72	73 TO 80	COLUMNS
	TITLE (ON EACH PAGE OF OUTPUT)							110.+0	N_C		IDENTITY	TITLE AND
	COMMENTS (ON FIRST PAGE OF OUTPUT)							I +0			"	COMMENTS
	N.+0	K_{ZN}.+0	K_{RO}.+0	K_{MO}.+0		K_{RN}.+0	K_{MN} +0	101.+0			"	END
		G_{ZN}	G_{RO}	G_{MO}		G_{RN}	G_{MN}	102.+0			"	CONDITIONS
	0.+0	R_o	Z_o					201.+0			'	R AND Z
	K_b.+0	R_b	Z_b	R_c		Z_c	S_e	20I.+0				
	K_a.+0	K_b.+0	H_a	H_b				30I.+0			'	H
	K_a.+0	K_b.+0	α	E_t		E_s	ν	40I +0			"	α, E, ν
	K_a.+0	$T_a(-H/2)$	$T_a(-H/4)$	$T_a(0)$		$T_a(H/4)$	$T_a(H/2)$	50I.+0			"	T
	K_b.+0	$T_b(-H/2)$	$T_b(-H/4)$	$T_b(0)$		$T_b(H/4)$	$T_b(H/2)$	50J +0			"	
	K_a.+0	K_b.+0	P_i	P_o				60I +0			"	P
	K_a.+0	K_b.+0	W_R	W_M		W_Z		70I +0			"	W
	K_a.+0	K_b.+0	K_{FFD}.+0		K_a.+0	K_b.+0	K_{FFD}.+0	80I +0			'	K_{FFD}
	K_a.+0	K_b.+0	K_{SS}.+0		K_a +0	K_b.+0	K_{SS}.+0	90I.+0			'	K_{SS}
								1001.+0			'	LAST CARD OF SET

BLANK CARD (BLANK IN ALL 80 COLUMNS)

CONFIDENTIAL

CONFIDENTIAL

NASA CR-72024
MND-3271

4 201 + 0 Card

R_o and Z_o are the radius and elevation at position zero

5 20I + 0 Cards (202, 203, etc)

K_b is the segment number at the end of a group of segments The remaining entries are defined as follows

R_b = radius at K_b

Z_b = elevation at K_b

R_c = radius at center of the ellipse or circle of the curved group

Z_c = elevation at center of the ellipse or circle of the curved group

S_e = 0 for a straight group of segments (no curvature) In this instance, R_c and Z_c are ignored

= ±1 for a curved group of segments (see Fig 3 for clarification)

Each segment should be entered if a stress and/or deflection is required at each segment

6 30I + 0 Cards

K_a = first segment of a group

K_b = last segment of a group

H_a = thickness on Segment K_a at Position K_a - 1

H_b = thickness on Segment K_b at Position K_b

The thickness increases linearly along each segment and at an in-between Position K, the thickness is

$$\left[(K_b - K) \times H_a + (K + 1 - K_a) \times H_b\right] \Big/ (K_b + 1 - K_a)$$

It is to be noted that each data card overrides the input of preceding cards For example, if

Card 301 has K_a = 1 and K_b = 40 and

Card 302 has K_a = 10 and K_b = 12,

then Segments 1 to 9 have the thicknesses of Card 301, Segments 10 to 12 have the thicknesses of Card 302, and Segments 13 to 40 have the thicknesses of Card 301

7 40I + 0 Cards

This set of cards permits the entry of material property data for each segment or group of segments where

α = coefficient of linear expansion (in /in -°F)

E_t = tensile modulus of elasticity (psi)

E_s = shear modulus of elasticity (psi)

where $E_s = \frac{E_t}{2(1 + \nu)}$

ν = Poisson's ratio ($0 \leq \nu \leq 0.5$)

8 50I + 0 Cards--Temperature Input

On each odd numbered card,

K_a = first segment of a group, $1 \leq K_a < N$

$T_a(y)$ = temperature at y for Position K_a - 1 on Segment K_a

Thus,

$T_a(-H/2)$ is at the outside surface,

$T_a(0)$ is at the middle surface, and

$T_a(+H/2)$ is at the inside surface

On the following even numbered card,

K_b = last segment of the group, $K_a \leq K_b \leq N$

$T_b(y)$ = temperature at y for Position K_b on Segment K_b

The temperature varies linearly in each segment from K_a to K_b, and each Segment K has the same total variation from K - 1 to K for $K = K_a$ to K_b

9 60I + 0 Cards

This group of cards presents the capability of entering internal and/or external pressure loading where

P_i = inside pressure on a segment or group

P_o = outside pressure on a segment or group

Pressure is always positive when the applied surface is under compression Note that a pressure can be applied to only one segment if desired This may be common when simulating a bolting or gasket load on a pressure vessel head

10 70I + 0 Cards

This series of cards enters the required ring loading for one or more K segments where

W_r = radial load (lb)

W_m = moment (in -lb)

W_z = axial load (lb)

These loads must be entered in their total circumferential magnitude, i e , a radial load of x lb/in is multipled by $2\pi R_1$ to obtain total load W_r in pounds

11 80I + 0 and 90I + 0 Cards

These cards are used to designate the output data (deflections, stresses) required by the user The 80I and 90I cards indicate deflections and stresses, respectively, whereby a code number is entered for K_{FFD} and K_{SS} This coding is defined as follows

$$K_{FFD} = 100\, K_{FA} + 10\, K_{FB} + K_{DB}$$

where

K_{DB} = 1 if the deflections and rotations are required at K_b (enter 0 if not required)

$K_{FA} = K_{FB}$ = 1 if the forces are required (enter 0 if not required)

Therefore, K_{FFD} = 111 for all force and deflection printout

$$K_{SS} = 10\,K_{SA} + K_{SB}$$

where

K_{SB} = 1 if stress printout is required at K_b (enter 0 if not required)

$K_{SA} = 4\,K_{0A} + 2\,K_{CA} + K_{IA}$

K_{0A} = 1 for stresses at $y = -\frac{H}{2}$

K_{CA} = 1 for stresses at $y = 0$

K_{IA} = 1 for stresses at $y = \frac{H}{2}$

K_{ij} = 0 where stress printout is not required

Therefore

K_{SS} = 77 to obtain all stress printout

12 1001 + 0 Card

This is the last card of each problem If a particular problem exists whereby two runs are necessary for the same geometry and, for example, only the temperature distribution changes, then the first complete problem deck is ended with a 1001 + 0 card and followed immediately with a 110 + 0 card, the second set of temperature cards, an additional 1001 + 0 card and finally by the required blank card to end the program

Thus, any number of cases may be incorporated for the geometry by incorporating only the variable input data additionally The program automatically returns to the beginning to search for the constant portions of the input for each case

Important Note

K_a and K_b must be entered for all input cards whether or not any additional data are entered For example, considering the pressure loading entries (Cards 60I + 0), if no pressure exists, enter K_a and K_b, the remaining entry locations are left blank (except card number)

It is most important that the layout of the segmented model be accurate and continually referenced during the process of writing input

D EXAMPLE PROBLEM AND OUTPUT DISCUSSION

To illustrate and discuss a typical program output, a simple problem was elected and solved The particular example consists of a circular cylinder (per Fig C-5) of length L where a local shear load normal to the axis of symmetry is imposed at a finite distance from the ends The analytical approach usually taken for the solution of this problem is via a differential equation solution of exponential form for two finite cylinders The final stress and displacement solutions are then dependent upon the slope and displacement compatibility at the junction of the two cylinders Hetenyi's "Beams on an Elastic Foundation" may be referenced for the mathematical description of the technology involved

The cylinder is divided into 18 segments to provide sufficient output stresses and deflections along the full length of the cylinder The shear load is incorporated by an equivalent pressure applied at Segment 15 The following material properties are applied

$$E = 26\ 5 \times 10^{6} \text{ psi}$$

$$\nu = 0\ 30$$

$$G = \frac{E}{2(1+\nu)} = 10\ 192 \times 10^{6} \text{ psi}$$

To best illustrate the particular input and output, a programming form and printout are included whereby detailed explanations and information are incorporated where necessary

The stress values are given at the beginning and end of each structural segment It is imperative that the required stress values at each segment interface be obtained by averaging the stress printout at the end of the ith segment and beginning of the (i + 1) segment for correct values The deflection and slope printout is given at the end of each segment For the particular example problem enclosed, the meridional stress, circumferential stress and deflection profiles are presented in Figs C-6 and C-7

The principal output data are as follows

1 Stresses

(1) Shear stress, TXY

(2) Meridional stress, SX

(3) Circumferential stress, SO

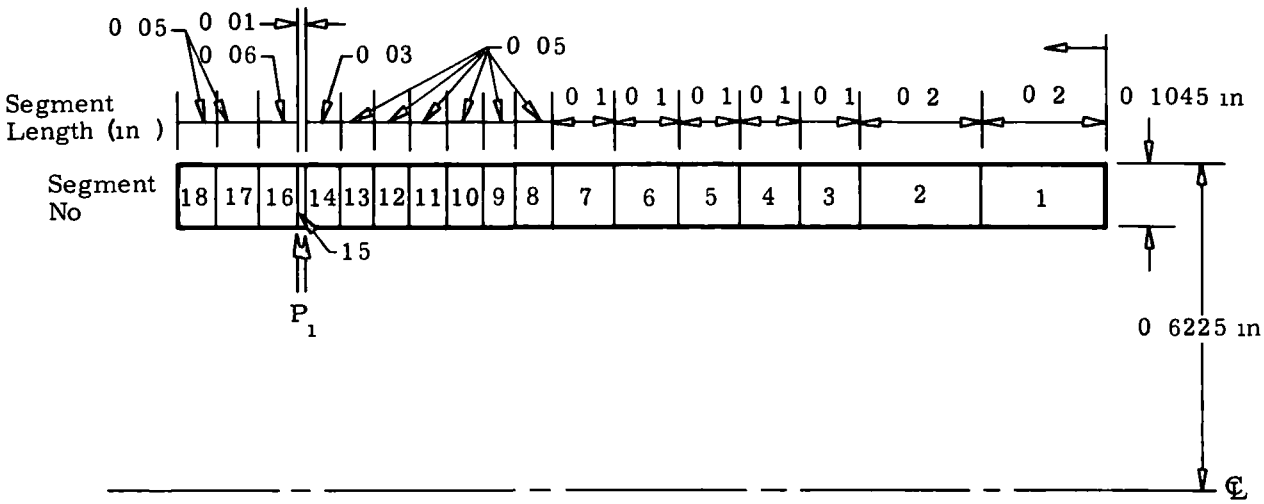


Fig C-5 Geometry and Segment Designation--Circular Cylinder

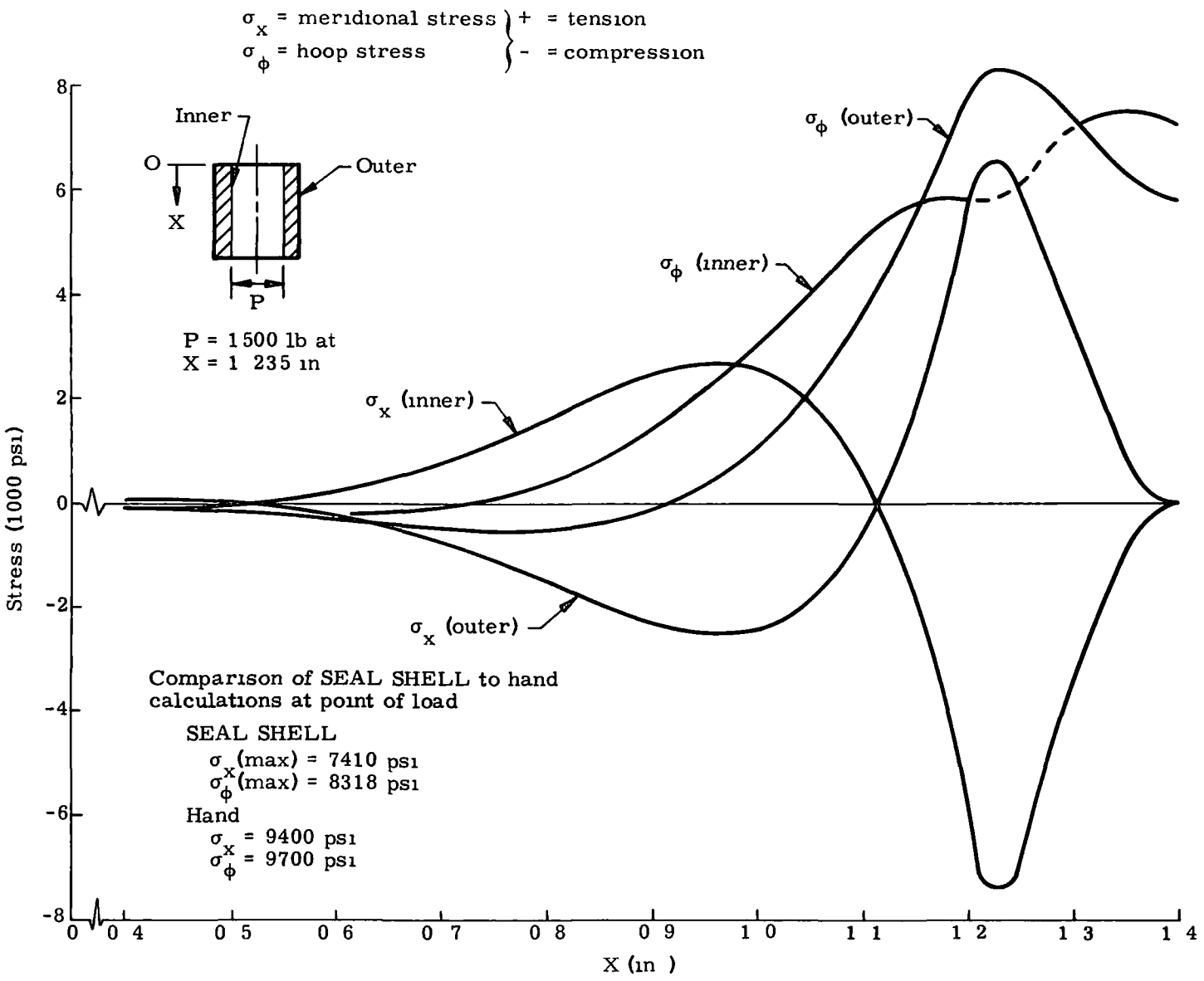


Fig C-6 Rod Locking Sleeve Stress Versus Axial Sleeve Location

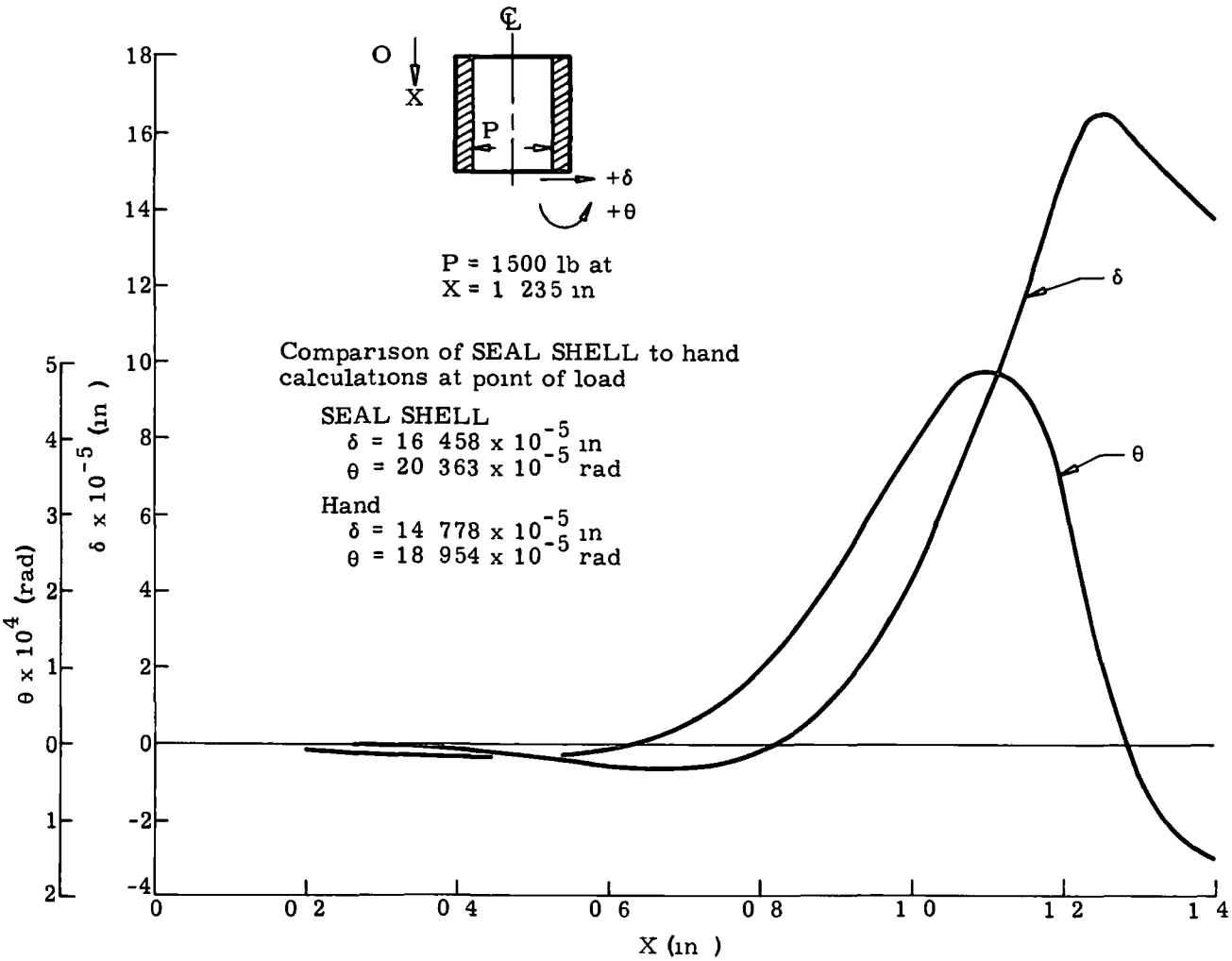


Fig C-7 Rod Locking Sleeve Deflection and Slope Versus Axial Sleeve Location

(4) Normal stress, SY

(5) Octahedral stress, SOCT

(6) Tresca criterion, 2TMAX

2 Deformations

(1) Radial deflection, DR

(2) Slope, DM

(3) Axial or longitudinal deformation, DZ

All of these values are given for the thermal strains, static load strains and the summation of the two in separate columns

MARTIN SYMBOLIC PROGRAMMING FORM

E 432 A (3 59)

TITLE _____ ANALYST _____

JOB NO _____ DATE _____ SHEET _____ OF _____

ITEM	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80
							1		+0								18.+0									77.+0								

MARTIN SYMBOLIC PROGRAMMING FORM

E 432 A (3 59)

TITLE _____ ANALYST _____

JOB NO _____ DATE _____ SHEET _____ OF _____

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*                FCR     SN200      02-104    3263-64C-21691          FASCHUMANN 8612
      STRESS ANALYSIS OF                    LOCKING SLEEVE                    110. +0 4
      THE RESULTS OF THIS PROBLEM WILL BE COMPARED DIRECTLY TO                  1  +0
      THE ANALYTICAL TREATMENT PER HETENYI WHERE RADIAL AND                     2  +0
      SLOPE COMPATIBILITY IS OBTAINED FOR A SHORT AND LONG                      3  +0
      CIRCULAR CYLINDER  LOAD ENTERED AS RING LOAD AT K15                       4  +0
                18 +0        1 +0        1 +0        1 +0        1 +0        101  +0
                                                                              102  +0
                0  +0    .57025          1 40                                201  +0
                1  +0     57025          1 20          0         0     0     202  +0
                2  +0     57025          1 00          0         0     0     203. +0
                3. +0     57025          0.90          0         0     0     204. +0
                4  +0     57025          0 80          0         0     0     205  +0
                5  +0     57025          0 70          0         0     0     206  +0
                6  +0     57025          0 60          0         0     0     207  +0
                7  +0     57025          0 50          0         0     0     208  +0
                8  +0    .57025          0 45          0         0     0     209  +0
                9  +0    .57025          0 40          0         0     0     210  +0
                10 +0     57025          0 35          0         0     0     211  +0
                11 +0     57025          0 30          0         0     0     212  +0
                12 +0     57025          0 25          0         0     0     213. +0
                13. +0   .57025          0.20          0         0     0     214. +0
                14 +0     57025          0 17          0         0     0     215  +0
                15 +0     57025          0 16          0         0     0     216. +0
                16 +0     57025          0 10          0         0     0     217. +0
                17 +0    .57025          0 05          0         0     0     218  +0
                18 +0     57025          0  0          0         0     0     219. +0
                1  +0     18 +0          1045      .1045                     301. +0
                1  +0     18 +0                    0    26 5E06 10 192E06   30  401  +0
                1  +0                  0           0          0         0     501  +0
                15 +0                  0           0          0         0     502. +0
                1  +0     14 +0                    0          0               601  +0
                15. +0    15 +0     4 61E04        0          0               602  +0
                16 +0     18 +0                    0          0               603  +0
                1  +0     18 +0                    0                    0    701. +0
                11 +0     18. +0      111 +0                                 801. +0
```

COMMENT CARDS ← SEE NOTE BELOW

NO TEMP INPUTS

INTERNAL PRES ONLY AT SEGMENT K15

PRINTOUT ALL DEFLECTIONS

NOTE IN THE FINAL EVALUATION OF THIS PROBLEM THE LOADING WAS ENTERED AS AN INTERNAL PRESSURE AT K15 (NOT AS A RING LOAD)

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STRESS ANALYSIS OF LOCKING SLEEVE
THE RESULTS OF THIS PROBLEM WILL BE COMPARED DIRECTLY TO 0.E 01
THE ANALYTICAL TREATMENT PER HETENYI WHERE RADIAL AND 0.E 01
SLOPE COMPATIBILITY IS OBTAINED FOR A SHORT AND LONG 0.E 01
CIRCULAR CYLINDER. LOAD ENTERED AS RING LOAD AT K15. 0.E 01

N	KZN	KRO	KMO	KRN	KMN	CARD
1.8000E 01	1.0000E 00	1.0000E 00	1.0000E 00	1.0000E 00	1.0000E 00	1.0100E 02

WZN	WRO	GMO	GRN	GMN	CARD
-0.	-0	-0.	-0.	-0.	1.0200E 02

KB	KB	ZB	RO	ZO	CURVE	CARD
0.	5.7025E-01	1.4000E 00	-0.	-0.	-0.	2.0100E 02
1.0000E 00	5.7025E-01	1.2000E 00	0.	0.	0.	2.0200E 02
2.0000E 00	5.7025E-01	1.0000E 00	0.	0.	0.	2.0300E 02
3.0000E 00	5.7025E-01	9.0000E-01	0.	0.	0.	2.0400E 02
4.0000E 00	5.7025E-01	8.0000E-01	0.	0.	0.	2.0500E 02
5.0000E 00	5.7025E-01	7.0000E-01	0.	0.	0	2.0600E 02
6.0000E 00	5.7025E-01	6.0000E-01	0.	0.	0.	2.0700E 02
7.0000E 00	5.7025E-01	5.0000E-01	0.	0.	0.	2.0800E 02
8.0000E 00	5.7025E-01	4.5000E-01	0.	0.	0.	2.0900E 02
9.0000E 00	5.7025E-01	4.0000E-01	0.	0	0	2.1000E 02
1.0000E 01	5.7025E-01	3.5000E-01	0.	0.	0.	2.1100E 02
1.1000E 01	5.7025E-01	3.0000E-01	0.	0.	0.	2.1200E 02
1.2000E 01	5.7025E-01	2.5000E-01	0.	0.	0.	2.1300E 02
1.3000E 01	5.7025E-01	2.0000E-01	0.	0	0	2.1400E 02
1.4000E 01	5.7025E-01	1.7000E-01	0.	0.	0.	2.1500E 02
1.5000E 01	5.7025E-01	1.6000E-01	0.	0.	0.	2.1600E 02
1.6000E 01	5.7025E-01	1.0000E-01	0.	0.	0	2.1700E 02
1.7000E 01	5.7025E-01	5.0000E-02	0.	0	0.	2.1800E 02
1.8000E 01	5.7025E-01	0.	0	0.	0.	2.1900E 02

INPUT DATA REPEATED

K	R(K-1)	R(K)	R(K+1)	R(K+2)	R(K+3)	R(K+4)	R(K+5)	R(K+6)	R(K+7)	R(K+8)
1	0.5702	0.5702	0.5702	0.5702	0.5702	0.5702	0.5702	0.5702	0.5702	0.5702
11	0.5702	0.5702	0.5702	0.5702	0.5702	0.5702	0.5702	0.5702	0.5702	

K	Z(K-1)	Z(K)	Z(K+1)	Z(K+2)	Z(K+3)	Z(K+4)	Z(K+5)	Z(K+6)	Z(K+7)	Z(K+8)
1	1.4000	1.2000	1.0000	0.9000	0.8000	0.7000	0.6000	0.5000	0.4500	0.4000
11	0.3500	0.3000	0.2500	0.2000	0.1700	0.1600	0.1000	0.0500	-0.	

KA	KB	HA	HB			CARD
1.0000E 00	1.8000E 01	1.0450E-01	1.0450E-01	-0	-0.	3.0100E 02

K	HA(K)	HA(K+1)	HA(K+2)	HA(K+3)	HA(K+4)	HA(K+5)	HA(K+6)	HA(K+7)	HA(K+8)	HA(K+9)
1	0.1045	0.1045	0.1045	0.1045	0.1045	0.1045	0.1045	0.1045	0.1045	0.1045
11	0.1045	0.1045	0.1045	0.1045	0.1045	0.1045	0.1045	0.1045		

K	HB(K)	HB(K+1)	HB(K+2)	HB(K+3)	HB(K+4)	HB(K+5)	HB(K+6)	HB(K+7)	HB(K+8)	HB(K+9)
1	0.1045	0.1045	0.1045	0.1045	0.1045	0.1045	0.1045	0.1045	0.1045	0.1045
11	0.1045	0.1045	0.1045	0.1045	0.1045	0.1045	0.1045	0.1045		

KA	KB	ALPHA	ET	ES	PR	CARD
1.0000E 00	1.8000E 01	0.	2.6500E 07	1.0192E 07	3.0000E-01	4.0100E 02

KA	TA1	TA2	TA3	TA4	TA5	CARD
KB	TB1	TB2	TB3	TB4	TB5	CARD
1.0000E 00	0.	0.	0.	0.	0.	5.0100E 02

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1.8000E 01 0 0 0 0 0 5.0200E 02
0.

KA	KB	PI	PO			CARD
1.0000E 00	1.4000E 01	0	0	-0.	-0	6.0100E 02
1.5000E 01	1.5000E 01	4.6100E 04	0	-0	-0.	6.0200E 02
1.6000E 01	1.8000E 01	0	0.	-0.	-0.	6.0300E 02

KA	KB	WR	WM	WZ	CARD
1.0000E 00	1.8000E 01	0	0.	0	-0.	7.0100E 02

KA	KB	KFFD	KA	KB	KFFD	CARD
1.0000E 01	1.8000E 01	1.1100E 02	-0.	-0.	-0.	8.0100E 02

KA	KB	KSS	KA	KB	KSS	CARD
1.0000E 00	1.8000E 01	7.7000E 01	-0	-0	-0.	9.0100E 02

FORCES (FZN, FRO, FMO, FRN, FMN) VS (T, P, W, GZN, GRO, GMO, GRN, GMN, SUM)

0	0	0	-0	0.	0.	0.	0.	-0.
0.	0	0.	0	-0	0	0.	0.	-0.
0.	0	0	0	0	-0.	0.	0.	-0.
0	0	0.	0	0	0	-0	0	-0.
0	0	0	0	0.	0	0	-0	-0

FLEXIBILITY MATRIX (DZN, DRO, DMO, DRN, DMN) VS (FT, FP, FM, FZN, FRO, FMO, FRN, FMN)

-0	-2.3732E-05	-0	1.4120E-07	1.4452E-08	3.0849E-08	-1.4443E-08	3.1314E-08
-0.	-6.3906E-07	-0.	1.4452E-08	3.5766E-07	-1.7515E-06	1.0092E-10	3.0855E-09
0	2.4276E-06	0	3.0849E-08	-1.7515E-06	1.9358E-05	-3.0284E-09	-2.7363E-08
0	1.3832E-04	0.	-1.4443E-08	1.2092E-10	-3.0284E-09	3.5368E-07	1.7565E-06
0	-1.4766E-04	0	3.1314E-08	3.0855E-09	-2.7363E-08	1.7565E-06	1.9646E-05

DEFLECTIONS (DZN, DRO, DMO, DRN, DMN) VS (T, P, W, GZN, GRO, GMO, GRN, GMN, SUM)

0	-2.3732E-05	0.	0.	0	0.	0.	-0.	-2.3732E-05
0	-6.3906E-07	0.	0	0	0	0	-0	-6.3906E-07
-0	2.4276E-06	-0	-0.	-0	-0	-0	0	2.4276E-06
0	1.3832E-04	0.	0.	0	0.	0.	-0	1.3832E-04
0	-1.4766E-04	0	0	0	0	0.	-0	-1.4766E-04

FORCES (FRX, FMX, FZX) VS (T, P, W, GZN, GRO, GMO, GRN, GMN, SUM) K = 1 AT U = 0.

0	-0.	0	0	0	0	0	-0	-0
0	-0	0.	0.	0	0.	0.	-0	-0
0	-0	0	0	0	0	0.	-0.	-0

FORCES (FRX, FMX, FZX) VS (T, P, W, GZN, GRO, GMO, GRN, GMN, SUM) K = 1 AT U = 1

-0	2.3718E 00	-0.	-0.	-0.	-0.	-0.	0.	2.3718E 00
0.	-3.0041E-01	0	0	0	0.	0	-0	-3.0041E-01
0	-0	0	0.	0.	0.	0.	-0.	-0.

DEFLECTIONS (DR, DM, DZ) VS (T, P, W, GZN, GRO, GMO, GRN, GMN, SUM) K = 1 AT U = 1.

THERMO DEFORMATIONS	0	LOAD DEFORM.	9.3619E-08	0.	0	0	0.	0	-0	9.3619E-08
	0.		-4.7884E-06	0	0.	0.	0.	0.	-0.	-4.7884E-06
	0		-4.4661E-08	0	0.	0	0.	0	-0	-4.4661E-08

FORCES (FRX, FMX, FZX) VS (T, P, W, GZN, GRO, GMO, GRN, GMN, SUM) K = 2 AT U = 0

-0	2.3718E 00	-0.	-0.	-0.	-0.	-0.	0	2.3718E 00
0.	-3.0041E-01	0.	0.	0	0.	0.	-0	-3.0041E-01
0.	-0.	0.	0.	0.	0.	0.	-0.	-0.

DEFLECTIONS ARE GIVEN AT THE END OF EACH SEGMENT (U=1)

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FORCES (FRX, FMX, FZX) VS (T, P, W, GZN, GRO, GMO, GRN, GMN, SUM) K = 2 AT U = 1.

-0.	-1.6915E 00	-0.	-0.	-0.	-0.	-0.	0.	-1.6915E 00
0.	-5.5691E-01	0.	0.	0.	0.	0.	-0.	-5.5691E-01
0.	-0.	0.	0.	0.	0.	0.	-0.	-0.

DEFLECTIONS (DR, DM, DZ) VS (T, P, W, GZN, GRO, GMO, GRN, GMN, SUM) K = 2 AT U = 1.

0.	-1.7276E-06	0.	0	0.	0.	0.	-0.	-1.7276E-06
0.	-1.4516E-05	0.	0.	0.	0.	0.	-0.	-1.4516E-05
0.	9.8727E-09	0.	0	0.	0.	0.	-0.	9.8727E-09

FORCES (FRX, FMX, FZX) VS (T, P, W, GZN, GRO, GMO, GRN, GMN, SUM) K = 3 AT U = 0.

-0.	-1.6915E 00	-0.	-0.	-0.	-0.	-0.	0.	-1.6915E 00
0.	-5.5691E-01	0.	0.	0.	0.	0.	-0.	-5.5691E-01
0.	-0.	0.	0.	0.	0.	0.	-0.	-0.

FORCES (FRX, FMX, FZX) VS (T, P, W, GZN, GRO, GMO, GRN, GMN, SUM) K = 3 AT U = 1.

-0.	-9.7215E 00	-0.	-0	-0.	-0.	-0.	0.	-9.7215E 00
0.	-2.8054E-02	0.	0.	0.	0.	0.	-0.	-2.8054E-02
0.	0.	0.	0.	0	0.	0.	-0.	0.

DEFLECTIONS (DR, DM, DZ) VS (T, P, W, GZN, GRO, GMO, GRN, GMN, SUM) K = 3 AT U = 1.

0.	-3.5628E-06	0.	0.	0.	0.	0.	-0.	-3.5628E-06
0	-1.7674E-05	0.	0.	0.	0.	0.	-0.	-1.7674E-05
0.	1.4328E-07	0.	0.	0.	0.	0.	-0.	1.4328E-07

FORCES (FRX, FMX, FZX) VS (T, P, W, GZN, GRO, GMO, GRN, GMN, SUM) K = 4 AT U = 0.

-0.	-9.7215E 00	-0.	-0	-0.	-0.	-0.	0.	-9.7215E 00
0	-2.8054E-02	0.	0.	0.	0.	0.	-0.	-2.8054E-02
0	0	0.	0.	0	0.	0	-0.	0.

FORCES (FRX, FMX, FZX) VS (T, P, W, GZN, GRO, GMO, GRN, GMN, SUM) K = 4 AT U = 1.

-0.	-2.3751E 01	-0.	-0.	-0.	-0.	-0.	0.	-2.3751E 01
0	1.6083E 00	0.	0.	0.	0.	0.	-0.	1.6083E 00
0.	0.	0.	0.	0.	0.	0.	-0.	0.

DEFLECTIONS (DR, DM, DZ) VS (T, P, W, GZN, GRO, GMO, GRN, GMN, SUM) K = 4 AT U = 1.

0.	-5.6145E-06	0.	0.	0	0.	0.	-0.	-5.6145E-06
0.	-1.0046E-05	0.	0.	0.	0.	0.	-0.	-1.0046E-05
0.	3.9735E-07	0.	0.	0.	0.	0.	-0.	3.9735E-07

FORCES (FRX, FMX, FZX) VS (T, P, W, GZN, GRO, GMO, GRN, GMN, SUM) K = 5 AT U = 0.

-0.	-2.3751E 01	-0.	-0.	-0	-0.	-0.	0.	-2.3751E 01
0	1.6083E 00	0.	0.	0.	0.	0	-0.	1.6083E 00
0.	0.	0.	0.	0.	0	0.	-0.	0.

FORCES (FRX, FMX, FZX) VS (T, P, W, GZN, GRO, GMO, GRN, GMN, SUM) K = 5 AT U = 1.

-0.	-4.2150E 01	-0.	-0.	-0.	-0.	-0.	0.	-4.2150E 01
0.	4.9157E 00	0.	0.	0.	0.	0.	-0	4.9157E 00
0.	0.	0.	0.	0.	0.	0.	-0.	0.

DEFLECTIONS (DR, DM, DZ) VS (T, P, W, GZN, GRO, GMO, GRN, GMN, SUM) K = 5 AT U = 1.

0.	-6.3086E-06	0.	0.	0.	0.	0.	-0.	-6.3086E-06
0.	2.2445E-05	0.	0.	0.	0.	0.	-0.	2.2445E-05
0.	7.6643E-07	0.	0.	0.	0.	0.	-0.	7.6643E-07

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FORCES (FRX, FMX, FZX) VS (T, P, W, GZN, GRO, GMO, GRN, GMN, SUM) K = 6 AT U = 0

-0	-4.2150E 01	-0.	-0.	-0.	-0.	-0.	0.	-4.2150E 01
0.	4.9157E 00	0.	0.	0.	0.	0.	-0.	4.9157E 00
0	0	0.	0.	0.	0.	0.	-0.	0.

FORCES (FRX, FMX, FZX) VS (T, P, W, GZN, GRO, GMO, GRN, GMN, SUM) K = 6 AT U = 1.

-0	-5.5799E 01	-0	-0.	-0	-0.	-0.	0	-5.5799E 01
0	9.9611E 00	0.	0.	0.	0.	0.	-0.	9.9611E 00
0	0	0	0	0.	0.	0.	-0.	0.

DEFLECTIONS (DR, DM, DZ) VS (T, P, W, GZN, GRO, GMO, GRN, GMN, SUM) K = 6 AT U = 1.

0	-2.2825E-06	0.	0	0	0	0.	-0.	-2.2825E-06
0.	9.7249E-05	0.	0.	0.	0.	0.	-0.	9.7249E-05
0	1.1211E-06	0.	0	0	0.	0.	-0.	1.1211E-06

FORCES (FRX, FMX, FZX) VS (T, P, W, GZN, GRO, GMO, GRN, GMN, SUM) K = 7 AT U = 0.

-0	-5.5799E 01	-0.	-0.	-0.	-0	-0.	0.	-5.5799E 01
0	9.9611E 00	0.	0.	0.	0.	0.	-0.	9.9611E 00
0.	0	0	0.	0	0	0.	-0	0.

FORCES (FRX, FMX, FZX) VS (T, P, W, GZN, GRO, GMO, GRN, GMN, SUM) K = 7 AT U = 1.

-0	-4.2190E 01	-0.	-0.	-0.	-0.	-0.	0.	-4.2190E 01
0	1.5268E 01	0	0	0	0	0	-0	1.5268E 01
0	0.	0.	0.	0.	0.	0.	-0	0.

DEFLECTIONS (DR, DM, DZ) VS (T, P, W, GZN, GRO, GMO, GRN, GMN, SUM) K = 7 AT U = 1.

0	1.1862E-05	0.	0	0.	0.	0	-0	1.1862E-05
0	2.2504E-04	0.	0.	0.	0.	0	-0.	2.2504E-04
0	1.0904E-06	0	0.	0.	0	0	-0.	1.0904E-06

FORCES (FRX, FMX, FZX) VS (T, P, W, GZN, GRO, GMO, GRN, GMN, SUM) K = 8 AT U = 0.

-0	-4.2190E 01	-0	-0	-0	-0.	-0.	0.	-4.2190E 01
0	1.5268E 01	0.	0.	0	0	0.	-0	1.5268E 01
0	0.	0	0	0	0.	0	-0	0.

FORCES (FRX, FMX, FZX) VS (T, P, W, GZN, GRO, GMO, GRN, GMN, SUM) K = 8 AT U = 1.

-0.	-1.3319E 01	-0.	-0.	-0	-0	-0.	0.	-1.3319E 01
0	1.6740E 01	0.	0	0.	0	0.	-0	1.6740E 01
0	0.	0.	0.	0	0.	0.	-0	0.

DEFLECTIONS (DR, DM, DZ) VS (T, P, W, GZN, GRO, GMO, GRN, GMN, SUM) K = 8 AT U = 1

0	2.4645E-05	0	0.	0	0.	0	-0.	2.4645E-05
0	3.0482E-04	0.	0	0	0.	0	-0	3.0482E-04
0	7.1995E-07	0.	0.	0.	0.	0.	-0.	7.1995E-07

FORCES (FRX, FMX, FZX) VS (T, P, W, GZN, GRO, GMO, GRN, GMN, SUM) K = 9 AT U = 0.

-0.	-1.3319E 01	-0.	-0.	-0	-0.	-0.	0.	-1.3319E 01
0	1.6740E 01	0	0	0.	0.	0	-0.	1.6740E 01
0.	0	0	0.	0	0	0.	-0	0.

FORCES (FRX, FMX, FZX) VS (T, P, W, GZN, GRO, GMO, GRN, GMN, SUM) K = 9 AT U = 1.

-0	3.8754E 01	-0.	-0	-0.	-0.	-0.	0.	3.8754E 01
0	1.6215E 01	0.	0	0.	0.	0	-0.	1.6215E 01
0.	0.	0.	0.	0.	0.	0.	-0.	0.

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DEFLECTIONS (DR, DM, DZ) VS (T, P, W, GZN, GRO, GMO, GRN, GMN, SUM) K = 9 AT U = 1.

0.	4.2135E-05	0.	0.	0.	0.	0.	-0.	4.2136E-05
0.	3.8612E-04	0.	0.	0.	0.	0.	-0.	3.8612E-04
0.	-4.8129E-08	0.	0.	0.	0.	0.	-0.	-4.8129E-08

FORCES (FRX, FMX, FZX) VS (T, P, W, GZN, GRO, GMO, GRN, GMN, SUM) K = 10 AT U = 0.

-0.	3.8754E 01	-0.	-0.	-0.	-0.	-0.	0.	3.8754E 01
0.	1.6215E 01	0.	0.	0.	0.	0.	-0.	1.6215E 01
0.	0	0.	0.	0.	0.	0.	-0.	0.

FORCES (FRX, FMX, FZX) VS (T, P, W, GZN, GRO, GMO, GRN, GMN, SUM) K = 10 AT U = 1.

-0.	1.2122E 02	-0.	-0.	-0.	-0.	-0.	0.	1.2122E 02
0.	1.2349E 01	0.	0	0.	0.	0.	-0.	1.2349E 01
0.	0.	0.	0.	0.	0.	0.	-0.	0.

DEFLECTIONS (DR, DM, DZ) VS (T, P, W, GZN, GRO, GMO, GRN, GMN, SUM) K = 10 AT U = 1.

0.	6.4514E-05	0.	0.	0.	0.	0.	-0.	6.4514E-05
0.	4.5517E-04	0.	0.	0.	0.	0.	-0.	4.5517E-04
0.	-1.3597E-06	0.	0.	0	0	0.	-0.	-1.3597E-06

FORCES (FRX, FMX, FZX) VS (T, P, W, GZN, GRO, GMO, GRN, GMN, SUM) K = 11 AT U = 0.

-0.	1.2122E 02	-0.	-0.	-0.	-0.	-0.	0.	1.2122E 02
0.	1 2349E 01	0	0.	0.	0.	0.	-0.	1.2349E 01
0	0.	0.	0.	0.	0.	0.	-0.	0.

FORCES (FRX, FMX, FZX) VS (T, P, W, GZN, GRO, GMO, GRN, GMN, SUM) K = 11 AT U = 1.

-0	2 4086E 02	-0	-0.	-0	-0.	-0	0.	2 4086E 02
0.	3 4466E 00	0.	0.	0.	0.	0.	-0.	3.4466E 00
0.	-0	0	0	0	0.	0.	-0	-0.

DEFLECTIONS (DR, DM, DZ) VS (T, P, W, GZN, GRO, GMO, GRN, GMN, SUM) K = 11 AT U = 1.

0.	9.1200E-05	0.	0.	0	0	0.	-0.	9.1200E-05
0.	4.9055E-04	0	0	0	0.	0	-0.	4.9055E-04
0.	-3.3662E-06	0.	0.	0	0.	0	-0.	-3.3662E-06

FORCES (FRX, FMX, FZX) VS (T, P, W, GZN, GRO, GMO, GRN, GMN, SUM) K = 12 AT U = 0.

-0.	2 4086E 02	-0	-0.	-0	-0.	-0.	0	2.4086E 02
0.	3.4466E 00	0.	0.	0.	0.	0.	-0.	3.4466E 00
0.	-0.	0.	0.	0.	0.	0.	-0.	-0.

FORCES (FRX, FMX, FZX) VS (T, P, W, GZN, GRO, GMO, GRN, GMN, SUM) K = 12 AT U = 1.

-0.	4.0257E 02	-0.	-0.	-0.	-0.	-0	0	4.0257E 02
0.	-1 2491E 01	0.	0.	0.	0.	0	-0	-1.2491E 01
0.	-0.	0.	0	0	0.	0.	-0	-0.

DEFLECTIONS (DR, DM, DZ) VS (T, P, W, GZN, GRO, GMO, GRN, GMN, SUM) K = 12 AT U = 1.

0.	1 2040E-04	0.	0.	0.	0.	0.	-0.	1.2040E-04
0.	4.6158E-04	0	0.	0.	0.	0.	-0.	4.6158E-04
0	-6 2006E-06	0	0.	0.	0.	0.	-0.	-6.2006E-06

FORCES (FRX, FMX, FZX) VS (T, P, W, GZN, GRO, GMO, GRN, GMN, SUM) K = 13 AT U = 0.

-0.	4.0257E 02	-0	-0.	-0.	-0.	-0.	0.	4.0257E 02
0.	-1.2491E 01	0.	0.	0	0.	0.	-0.	-1 2491E 01
0.	-0.	0.	0.	0.	0.	0.	-0.	-0.

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FORCES (FRX, FMX, FZX) VS (T, P, W, GZN, GRO, GMO, GRN, GMN, SUM) K = 13 AT U = 1.

-0	6.0703E 02	-0	-0	-0.	-0.	-0.	0.	6.0703E 02
0.	-3.7610E 01	0	0	0.	0.	0.	-0	-3.7610E 01
0	-0	0	0.	0.	0.	0.	-0.	-0.

DEFLECTIONS (DR, DM, DZ) VS (T, P, W, GZN, GRO, GMO, GRN, GMN, SUM) K = 13 AT U = 1.

0	1.4860E-04	0	0.	0	0	0.	-0.	1.4860E-04
0.	3.2724E-04	0.	0.	0.	0.	0.	-0.	3.2724E-04
0	-9.9401E-06	0.	0	0.	0.	0.	-0	-9.9401E-06

FORCES (FRX, FMX, FZX) VS (T, P, W, GZN, GRO, GMO, GRN, GMN, SUM) K = 14 AT U = 0

-0	6.0703E 02	-0.	-0.	-0	-0.	-0.	0	6.0703E 02
0.	-3.7610E 01	0	0.	0	0.	0.	-0.	-3.7610E 01
0.	-0.	0.	0.	0.	0.	0.	-0.	-0.

FORCES (FRX, FMX, FZX) VS (T, P, W, GZN, GRO, GMO, GRN, GMN, SUM) K = 14 AT U = 1.

-0	7.4786E 02	-0.	-0.	-0.	-0	-0.	0.	7.4786E 02
0.	-5.7918E 01	0.	0.	0.	0.	0.	-0.	-5.7918E 01
0.	-0.	0.	0.	0.	0.	0.	-0	-0.

DEFLECTIONS (DR, DM, DZ) VS (T, P, W, GZN, GRO, GMO, GRN, GMN, SUM) K = 14 AT U = 1.

0.	1.6268E-04	0	0.	0.	0.	0	-0.	1.6268E-04
0	1.7518E-04	0.	0	0.	0.	0.	-0	1.7518E-04
0	-1.2611E-05	0	0	0.	0.	0.	-0.	-1.2611E-05

FORCES (FRX, FMX, FZX) VS (T, P, W, GZN, GRO, GMO, GRN, GMN, SUM) K = 15 AT U = 0.

-0	7.4786E 02	-0.	-0	-0	-0	-0.	0.	7.4786E 02
0	-5.7918E 01	0.	0.	0.	0.	0.	-0.	-5.7918E 01
0.	-0	0	0	0	0.	0	-0	-0

FORCES (FRX, FMX, FZX) VS (T, P, W, GZN, GRO, GMO, GRN, GMN, SUM) K = 15 AT U = 1

-0.	-7.4307E 02	-0.	-0.	-0.	-0.	-0.	0.	-7.4307E 02
0	-5.7942E 01	0.	0.	0.	0.	0.	-0.	-5.7942E 01
0	-0	0.	0.	0.	0.	0.	-0.	-0.

DEFLECTIONS (DR, DM, DZ) VS (T, P, W, GZN, GRO, GMO, GRN, GMN, SUM) K = 15 AT U = 1

0	1.6458E-04	0.	0	0	0.	0.	-0	1.6458E-04
0.	2.0363E-04	0.	0.	0.	0.	0.	-0.	2.0363E-04
0.	-1.0359E-05	0	0.	0	0.	0.	-0	-1.0359E-05

FORCES (FRX, FMX, FZX) VS (T, P, W, GZN, GRO, GMO, GRN, GMN, SUM) K = 16 AT U = 0.

-0	-7.4307E 02	-0.	-0.	-0.	-0.	-0.	0.	-7.4307E 02
0	-5.7942E 01	0	0	0	0.	0.	-0	-5.7942E 01
0.	-0.	0	0	0	0.	0.	-0.	-0.

FORCES (FRX, FMX, FZX) VS (T, P, W, GZN, GRO, GMO, GRN, GMN, SUM) K = 16 AT U = 1.

-0	-4.5007E 02	-0.	-0	-0.	-0.	-0.	0	-4.5007E 02
0	-2.2097E 01	0	0	0	0.	0	-0.	-2.2097E 01
0.	-0	0.	0.	0.	0.	0.	-0	-0.

DEFLECTIONS (DR, DM, DZ) VS (T, P, W, GZN, GRO, GMO, GRN, GMN, SUM) K = 16 AT U = 1.

0.	1.5693E-04	0	0	0.	0	0.	-0.	1.5693E-04
0.	-4.7429E-05	0	0.	0.	0.	0.	-0.	-4.7429E-05
0.	-1.5812E-05	0.	0.	0.	0.	0.	-0.	-1.5812E-05

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FORCES (FRX, FMX, FZX) VS (T, P, W, GZN, GRO, GMO, GRN, GMN, SUM) K = 17 AT U = 0.

-0.	-4.5007E 02	-0.	-0.	-0.	-0.	-0.	0.	-4.5007E 02
0	-2.2097E 01	0.	0.	0.	0.	0.	-0.	-2.2097E 01
0.	-0.	0.	0.	0.	0.	0.	-0.	-0.

FORCES (FRX, FMX, FZX) VS (T, P, W, GZN, GRO, GMO, GRN, GMN, SUM) K = 17 AT U = 1.

-0	-2 1823E 02	-0.	-0.	-0.	-0.	-0.	0	-2 1823E 02
0.	-5.4133E 00	0.	0.	0.	0.	0.	-0.	-5.4133E 00
0.	0.	0	0.	0.	0.	0.	-0.	-0.

DEFLECTIONS (DR, DM, DZ) VS (T, P, W, GZN, GRO, GMO, GRN, GMN, SUM) K = 17 AT U = 1.

0.	1.4699E-04	0.	0.	0.	0.	0.	-0.	1.4699E-04
0.	-1.2572E-04	0	0.	0.	0.	0.	-0	-1 2572E-04
0.	-1.9934E-05	0.	0.	0.	0.	0.	-0.	-1.9934E-05

FORCES (FRX, FMX, FZX) VS (T, P, W, GZN, GRO, GMO, GRN, GMN, SUM) K = 18 AT U = 0.

-0.	-2.1823E 02	-0.	-0.	-0.	-0.	-0.	0.	-2.1823E 02
0.	-5.4133E 00	0.	0.	0.	0.	0.	-0.	-5.4133E 00
0.	0.	0.	0.	0.	0.	0.	-0	-0.

FORCES (FRX, FMX, FZX) VS (T, P, W, GZN, GRO, GMO, GRN, GMN, SUM) K = 18 AT U = 1.

0.	0.	0.	0.	0.	0.	-0.	0.	-0.
0.	0	0.	0.	0.	0.	0.	-0.	-0.
0.	0.	0.	-0.	0.	0.	0.	0.	-0.

DEFLECTIONS (DR, DM, DZ) VS (T, P, W, GZN, GRO, GMO, GRN, GMN, SUM) K = 18 AT U = 1.

0.	1 3832E-04	0	0.	0.	0.	0.	-0.	1.3832E-04
0.	-1.4766E-04	0.	0.	0.	0.	0.	-0	-1.4766E-04
0	-2.3732E-05	0.	0.	0.	0	0.	-0.	-2.3732E-05

STRESSES(TXY, SX, SO, SY, SOCT, 2TMAX) VS (T, P, W, ZN, RO, MO, RN, MN, SUM) AT K = 1, U = 0., Y = -0.0522 OUTER SURFACE

-0	0.	-0	-0	-0.	-0	-0	0		0.
-0.	-6.	-0	-0.	-0.	-0	-0	0		-6.
-0	26.	-0	-0	-0	-0.	-0	0.		26.
-0	-0.	-0	-0.	-0.	-0.	-0	0.		-0.
1	29	1	1.	1	1	1.	1.		29.
1	32.	1	1.	1.	1.	1.	1		32.

STRESSES(TXY, SX, SO, SY, SOCT, 2TMAX) VS (T, P, W, ZN, KO, MO, RN, MN, SUM) AT K = 1, U = 0., Y = 0. MID SURFACE

0.	-0.	0.	0.	0	0	0.	-0		-0.
-0	0.	-0	-0	-0.	-0.	-0.	0.		0.
-0	31.	-0	-0.	-0	-0	-0	0.		31.
-0.	-0.	-0	-0.	-0.	-0.	-0.	0		-0.
1	31	1	1.	1	1	1.	1.		31.
1	31.	1.	1.	1	1	1.	1.		31.

STRESSES(TXY, SX, SO, SY, SOCT, 2TMAX) VS (T, P, W, ZN, KO, MO, RN, MN, SUM) AT K = 1, U = 0., Y = 0.0522 INNER SURFACE

-0.	0.	-0	-0.	-0.	-0.	-0	-0	0.	0.
-0	7.	-0	-0.	-0.	-0.	-0	0		7.
-0.	37	-0.	-0	-0	-0	-0.	0.		37.
-0	-0.	-0.	-0.	-0.	-0.	-0.	0.		-0.
1	34.	1.	1.	1.	1.	1.	1.		34.
1	37	1.	1.	1.	1.	1.	1.		37.

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STATIC LOAD STRESSES

TOTAL STRESSES

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STRESSES(TXY, SX, SO, SY, SOCT, 2TMAX) VS (T, P, W, ZN, RO, MO, RN, MN, SUM) AT K = 1, U = 1., Y = -0.0522

-0.	0	-0	-0	-0.	-0	-0.	0.	0.
-0.	40.	-0.	-0	-0.	-0.	-0	0	40.
-0	13.	-0.	-0.	-0.	-0.	-0.	0.	13.
-0	-0.	-0	-0	-0.	-0	-0.	0.	-0.
1	35.	1.	1.	1.	1.	1.	1.	35
1	40	1.	1.	1	1	1.	1.	40.

STRESSES(TXY, SX, SO, SY, SOCT, 2TMAX) VS (T, P, W, ZN, RO, MO, RN, MN, SUM) AT K = 1, U = 1., Y = 0.

0.	-10.	0.	0.	0.	0.	0.	-0.	-10.
-0	-1.	-0.	-0.	-0.	-0.	-0	0.	-1.
-0	2	-0.	-0	-0	-0.	-0.	0	2.
-0	-0	-0.	-0.	-0.	-0	-0.	0.	-0.
1	17.	1.	1.	1.	1.	1.	1.	17.
1.	19	1	1	1.	1.	1.	1.	19.

STRESSES(TXY, SX, SO, SY, SOCT, 2TMAX) VS (T, P, W, ZN, RO, MO, RN, MN, SUM) AT K = 1, U = 1., Y = 0.0522

-0.	0	-0.	-0.	-0.	-0.	-0.	0	0.
-0.	-43.	-0.	-0.	-0.	-0.	-0.	0.	-43.
-0.	-11.	-0	-0	-0.	-0	-0	0.	-11.
-0	-0	-0	-0	-0.	-0.	-0.	0.	-0.
1	38.	1	1	1.	1	1.	1.	38.
1	43.	1.	1.	1.	1	1.	1.	43.

STRESSES(TXY, SX, SO, SY, SOCT, 2TMAX) VS (T, P, W, ZN, RO, MO, RN, MN, SUM) AT K = 2, U = 0., Y = -0.0522

-0	0.	-0.	-0.	-0.	-0.	-0.	0.	0.
-0	52.	-0	-0.	-0.	-0	-0.	0	52.
-0.	20.	-0.	-0.	-0.	-0.	-0.	0.	20.
-0	-0.	-0	-0	-0.	-0.	-0	0.	-0.
1.	46.	1.	1.	1.	1.	1.	1.	46.
1	52	1.	1	1.	1	1.	1.	52.

STRESSES(TXY, SX, SO, SY, SOCT, 2TMAX) VS (T, P, W, ZN, RO, MO, RN, MN, SUM) AT K = 2, U = 0., Y = 0.

0	-10.	0	0.	0	0	0	-0.	-10.
-0.	-2.	-0.	-0	-0	-0	-0	0.	-2.
-0	4.	-0	-0.	-0.	-0.	-0.	0.	4.
-0	-3.	-0	-0.	-0.	-0	-0.	0.	-3.
1	18	1.	1.	1.	1	1.	1.	18.
1	19.	1	1.	1.	1	1	1	19.

STRESSES(TXY, SX, SO, SY, SOCT, 2TMAX) VS (T, P, W, ZN, RO, MO, RN, MN, SUM) AT K = 2, U = 0., Y = 0.0522

-0	0	-0.	-0.	-0.	-0.	-0.	0.	0.
-0.	-55.	-0.	-0.	-0	-0	-0.	0	-55.
-0.	-11.	-0.	-0.	-0.	-0.	-0.	0.	-11.
-0	-0	-0	-0.	-0.	-0.	-0	0	-0.
1.	51.	1	1.	1.	1.	1.	1.	51.
1	55.	1	1	1.	1.	1.	1.	55.

STRESSES(TXY, SX, SO, SY, SOCT, 2TMAX) VS (T, P, W, ZN, RO, MO, RN, MN, SUM) AT K = 2, U = 1., Y = -0.0522

-0.	0.	-0.	-0.	-0.	-0.	-0.	0.	0.
-0.	94.	-0.	-0.	-0.	-0	-0.	0.	94.
-0	-45.	-0.	-0.	-0.	-0	-0.	0.	-45.
-0	-0.	-0.	-0.	-0.	-0.	-0.	0	-0.
1.	123.	1.	1.	1.	1.	1	1.	123.
1.	139	1.	1.	1.	1.	1.	1	139.

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STRESSES(TXY, SX, SO, SY, SOCT, 2TMAX) VS (T, P, W, ZN, RO, MO, RN, MN, SUM) AT K = 2, U = 1., Y = 0.

0.	7.	0.	0.	0.	0.	0.	-0.	7.
-0.	-3.	-0.	-0.	-0.	-0.	-0.	0.	-3.
-0.	-82.	-0.	-0.	-0.	-0.	-0.	0.	-82.
-0.	-3.	-0	-0.	-0.	-0.	-0	0.	-3.
1	79.	1.	1.	1.	1.	1.	1.	79.
1.	85	1.	1.	1.	1.	1.	1.	85.

STRESSES(TXY, SX, SO, SY, SOCT, 2TMAX) VS (T, P, W, ZN, RO, MO, RN, MN, SUM) AT K = 2, U = 1., Y = 0.0522

-0.	0.	-0.	-0.	-0.	-0.	-0.	0.	0.
-0.	-101.	-0.	-0.	-0.	-0.	-0.	0.	-101.
-0	-123.	-0.	-0.	-0.	-0.	-0.	0.	-123.
-0.	-0.	-0.	-0.	-0.	-0.	-0.	0.	-0.
1.	113.	1.	1.	1.	1.	1.	1.	113.
1	122.	1.	1.	1	1.	1.	1.	122.

STRESSES(TXY, SX, SO, SY, SOCT, 2TMAX) VS (T, P, W, ZN, RO, MO, RN, MN, SUM) AT K = 3, U = 0., Y = -0.0522

-0.	0.	-0.	-0.	-0.	-0.	-0.	0.	0.
-0.	91.	-0	-0.	-0.	-0.	-0.	0.	91.
-0.	-49.	-0.	-0.	-0.	-0.	-0.	0.	-49.
-0	-0	-0	-0.	-0.	-0	-0.	0.	-0.
1.	122.	1.	1.	1.	1.	1.	1.	122.
1.	139.	1.	1.	1.	1.	1.	1.	139.

STRESSES(TXY, SX, SO, SY, SOCT, 2TMAX) VS (T, P, W, ZN, RO, MO, RN, MN, SUM) AT K = 3, U = 0., Y = 0.

0.	7.	0.	0.	0.	0.	0.	-0.	7.
-0.	-4.	-0.	-0.	-0	-0.	-0	0	-4.
-0	-85.	-0.	-0.	-0.	-0.	-0.	0	-85.
-0.	-3	-0	-0.	-0.	-0.	-0.	0.	-3.
1.	83.	1.	1.	1.	1.	1.	1.	83.
1.	89	1.	1.	1.	1.	1.	1.	89.

STRESSES(TXY, SX, SO, SY, SOCT, 2TMAX) VS (T, P, W, ZN, RO, MO, RN, MN, SUM) AT K = 3, U = 0., Y = 0.0522

-0.	0.	-0.	-0.	-0.	-0	-0.	0.	0.
-0.	-97	-0	-0	-0	-0	-0.	0.	-97.
-0	-125	-0.	-0.	-0.	-0.	-0.	0.	-125.
-0	-0	-0.	-0.	-0.	-0	-0.	0.	-0.
1.	113.	1.	1.	1.	1.	1.	1.	113.
1	125.	1.	1.	1	1.	1	1.	125.

STRESSES(TXY, SX, SO, SY, SOCT, 2TMAX) VS (T, P, W, ZN, RO, MO, RN, MN, SUM) AT K = 3, U = 1., Y = -0.0522

-0.	0	-0.	-0	-0.	-0.	-0.	0.	0.
-0	12.	-0.	-0.	-0	-0.	-0.	0.	12.
-0	-140.	-0	-0.	-0	-0.	-0	0.	-140.
-0.	-0.	-0	-0.	-0.	-0	-0.	0.	-0.
1	146	1	1.	1	1.	1.	1	146.
1.	151.	1.	1.	1.	1.	1.	1.	151.

STRESSES(TXY, SX, SO, SY, SOCT, 2TMAX) VS (T, P, W, ZN, RO, MO, RN, MN, SUM) AT K = 3, U = 1., Y = 0.

0.	39.	0.	0.	0.	0.	0.	-0	39.
-0.	-1.	-0.	-0.	-0.	-0.	-0.	0.	-1.
-0.	-162.	-0.	-0.	-0	-0.	-0.	0.	-162.
-0	-3	-0	-0.	-0.	-0	-0	0.	-3.
1	173.	1.	1.	1.	1.	1.	1.	173.
1	199.	1.	1.	1.	1.	1.	1.	199.

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STRESSES(TXY, SX, SO, SY, SOCT, 2TMAX) VS (T, P, W, ZN, RO, MO, RN, MN, SUM) AT K = 3, U = 1., Y = 0.0522

-0	0.	-0	-0.	-0.	-0.	-0.	0.	0.
-0	-13.	-0.	-0.	-0.	-0.	-0.	0.	-13.
-0.	-186.	-0.	-0.	-0.	-0.	-0.	0.	-186.
-0.	-0.	-0.	-0.	-0.	-0	-0	0.	-0.
1.	179	1	1.	1.	1	1.	1.	179.
1.	185.	1	1.	1.	1.	1.	1.	185.

STRESSES(TXY, SX, SO, SY, SOCT, 2TMAX) VS (T, P, W, ZN, RO, MO, RN, MN, SUM) AT K = 4, U = 0., Y = -0.0522

-0	-0.	-0.	-0.	-0.	-0.	-0.	0.	-0.
-0	17.	-0.	-0.	-0.	-0.	-0.	0.	17.
-0	-152.	-0	-0.	-0.	-0.	-0.	0.	-152.
-0.	0.	-0.	-0.	-0.	-0	-0.	0.	0.
1	161.	1.	1.	1.	1.	1.	1.	161.
1.	169	1.	1.	1.	1.	1.	1.	169.

STRESSES(TXY, SX, SO, SY, SOCT, 2TMAX) VS (T, P, W, ZN, RO, MO, RN, MN, SUM) AT K = 4, U = 0., Y = 0.

0	39	0.	0.	0	0.	0.	-0.	39.
-0.	-0	-0.	-0.	-0.	-0	-0.	0.	-0.
-0.	-176.	-0.	-0.	-0.	-0.	-0.	0.	-176.
-0.	-0	-0	-0	-0	-0.	-0.	0.	-0.
1	189.	1.	1.	1.	1.	1.	1.	189.
1	215.	1	1	1	1.	1.	1.	215.

STRESSES(TXY, SX, SO, SY, SOCT, 2TMAX) VS (T, P, W, ZN, RO, MO, RN, MN, SUM) AT K = 4, U = 0., Y = 0.0522

-0	-0.	-0.	-0.	-0.	-0.	-0.	0.	-0.
-0	-19.	-0	-0.	-0.	-0.	-0.	0.	-19.
-0	-205.	-0	-0.	-0.	-0.	-0.	0.	-205.
-0	0	-0.	-0.	-0	-0.	-0.	0.	0.
1.	196.	1.	1.	1.	1.	1.	1.	196.
1.	205.	1	1	1.	1	1.	1.	205.

STRESSES(TXY, SX, SO, SY, SOCT, 2TMAX) VS (T, P, W, ZN, RO, MO, RN, MN, SUM) AT K = 4, U = 1., Y = -0.0522

-0.	-0	-0	-0.	-0.	-0.	-0.	0.	-0.
-0	-227.	-0.	-0	-0.	-0.	-0.	0.	-227.
-0	-284.	-0	-0.	-0	-0.	-0	0.	-284.
-0.	0.	-0	-0.	-0	-0.	-0.	0.	0.
1	260	1	1	1.	1.	1.	1.	260.
1.	284.	1	1.	1.	1.	1.	1.	284.

STRESSES(TXY, SX, SO, SY, SOCT, 2TMAX) VS (T, P, W, ZN, RO, MO, RN, MN, SUM) AT K = 4, U = 1., Y = 0.

0.	95.	0	0.	0.	0.	0.	-0.	95.
-0	7	-0.	-0	-0.	-0.	-0.	0.	7.
-0.	-245.	-0.	-0.	-0.	-0.	-0.	0.	-245.
-0.	-0	-0	-0.	-0	-0.	-0	0.	-0.
1	298	1	1	1.	1	1.	1.	298.
1.	343.	1.	1.	1	1.	1.	1.	343.

STRESSES(TXY, SX, SO, SY, SOCT, 2TMAX) VS (T, P, W, ZN, RO, MO, RN, MN, SUM) AT K = 4, U = 1., Y = 0.0522

-0	-0	-0	-0	-0	-0.	-0.	0.	-0.
-0.	241.	-0.	-0.	-0.	-0.	-0.	0.	241.
-0.	-202.	-0	-0	-0.	-0	-0	0	-202.
-0	0.	-0	-0.	-0.	-0.	-0.	0.	0.
1	384.	1.	1.	1.	1.	1.	1.	384.
1.	443.	1.	1.	1.	1.	1.	1.	443.

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STRESSES(TXY, SX, SO, SY, SOCT, 2TMAX) VS (T, P, W, ZN, RO, MO, RN, MN, SUM) AT K = 5, U = 0., Y = -0.0522

-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	0.	-0.
-0.	-223.	-0.	-0.	-0.	-0.	-0.	-0.	0.	-223.
-0.	-314.	-0.	-0.	-0.	-0.	-0.	-0.	0.	-314.
-0.	1.	-0.	-0.	-0.	-0.	-0.	-0.	0.	1.
1.	281.	1.	1.	1.	1.	1.	1.	1.	281.
1.	316.	1.	1.	1.	1.	1.	1.	1.	316.

STRESSES(TXY, SX, SO, SY, SOCT, 2TMAX) VS (T, P, W, ZN, RO, MO, RN, MN, SUM) AT K = 5, U = 0., Y = 0.

0.	95.	0.	0.	0.	0.	0.	-0.	0.	95.
-0.	10.	-0.	-0.	-0.	-0.	-0.	-0.	0.	10.
-0.	-277.	-0.	-0.	-0.	-0.	-0.	-0.	0.	-277.
-0.	9.	-0.	-0.	-0.	-0.	-0.	-0.	0.	9.
1.	331.	1.	1.	1.	1.	1.	1.	1.	331.
1.	382.	1.	1.	1.	1.	1.	1.	1.	382.

STRESSES(TXY, SX, SO, SY, SOCT, 2TMAX) VS (T, P, W, ZN, RO, MO, RN, MN, SUM) AT K = 5, U = 0., Y = 0.0522

-0	-0.	-0.	-0.	-0.	-0.	-0.	-0.	0.	-0.
-0.	237.	-0	-0.	-0.	-0.	-0.	-0.	0.	237.
-0.	-244.	-0.	-0.	-0.	-0.	-0.	-0.	0.	-244.
-0.	1.	-0.	-0.	-0.	-0.	-0.	-0.	0.	1.
1.	416.	1.	1.	1.	1.	1.	1.	1.	416.
1	480.	1.	1.	1.	1.	1.	1.	1.	480.

STRESSES(TXY, SX, SO, SY, SOCT, 2TMAX) VS (T, P, W, ZN, RO, MO, RN, MN, SUM) AT K = 5, U = 1., Y = -0.0522

-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	0.	-0.
-0.	-715	-0.	-0.	-0.	-0.	-0.	-0.	0.	-715.
-0.	-440.	-0.	-0.	-0.	-0.	-0.	-0.	0.	-440.
-0	1	-0	-0.	-0.	-0	-0.	-0.	0.	1.
1	626.	1.	1.	1.	1.	1.	1.	1.	626.
1.	716	1.	1.	1.	1.	1.	1.	1.	716.

STRESSES(TXY, SX, SO, SY, SOCT, 2TMAX) VS (T, P, W, ZN, RO, MO, RN, MN, SUM) AT K = 5, U = 1., Y = 0.

0.	169.	0	0.	0.	0.	0.	-0	0.	169.
-0.	23.	-0.	-0.	-0.	-0.	-0.	-0.	0.	23.
-0	-257.	-0.	-0.	-0	-0.	-0.	-0.	0.	-257.
-0	9.	-0.	-0.	-0.	-0.	-0.	-0.	0.	9.
1.	401	1	1.	1	1	1	1.	1.	401.
1.	442.	1.	1.	1	1.	1.	1.	1.	442.

STRESSES(TXY, SX, SO, SY, SOCT, 2TMAX) VS (T, P, W, ZN, RO, MO, RN, MN, SUM) AT K = 5, U = 1., Y = 0.0522

-0.	-0.	-0.	-0	-0.	-0	-0	0.	0.	-0.
-0.	762.	-0.	-0.	-0.	-0.	-0.	-0.	0.	762.
-0.	-58.	-0	-0.	-0.	-0.	-0.	-0.	0.	-58.
-0.	1.	-0.	-0.	-0	-0.	-0.	-0.	0.	1.
1.	791.	1.	1.	1	1	1.	1.	1.	791.
1.	819	1.	1.	1	1.	1.	1.	1.	819.

STRESSES(TXY, SX, SO, SY, SOCT, 2TMAX) VS (T, P, W, ZN, RO, MO, RN, MN, SUM) AT K = 6, U = 0., Y = -0.0522

-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	0.	-0.
-0.	-720.	-0.	-0.	-0	-0.	-0.	-0.	0.	-720.
-0	-495	-0.	-0.	-0.	-0.	-0.	-0.	0.	-495.
-0.	4.	-0.	-0.	-0.	-0.	-0.	-0.	0.	4.
1.	642.	1.	1.	1.	1.	1.	1.	1.	642.
1.	724.	1.	1.	1.	1.	1.	1.	1.	724.

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STRESSES(TXY, SX, SO, SY, SOCT, 2TMAX) VS (T, P, W, ZN, RO, MO, RN, MN, SUM) AT K = 6, U = 0., Y = 0.

0.	169	0.	0.	0.	0.	0.	-0.	169.
-0	31	-0.	-0	-0	-0.	-0.	0	31.
-0	-310	-0.	-0.	-0.	-0.	-0.	0.	-310.
-0.	28.	-0	-0.	-0	-0.	-0	0.	28.
1	448.	1.	1.	1.	1.	1.	1.	448.
1	508.	1.	1.	1.	1.	1	1.	508.

STRESSES(TXY, SX, SO, SY, SOCT, 2TMAX) VS (T, P, W, ZN, RO, MO, RN, MN, SUM) AT K = 6, U = 0., Y = 0.0522

-0.	-0	-).	-0.	-0.	-0.	-0.	0.	-0.
-0.	767.	-0	-0.	-0	-0.	-0.	0.	767.
-0.	-124.	-0	-0.	-0.	-0.	-0	0.	-124.
-0	4.	-0.	-0.	-0	-0.	-0.	0.	4.
1.	835.	1.	1.	1.	1.	1.	1.	835.
1.	891	1.	1.	1.	1.	1.	1.	891.

STRESSES(TXY, SX, SO, SY, SOCT, 2TMAX) VS (T, P, W, ZN, RO, MO, RN, MN, SUM) AT K = 6, U = 1., Y = -0.0522

-0	-0.	-0.	-0.	-0.	-0.	-0.	0.	-0.
-0	-1470	-0.	-0.	-0.	-0	-0.	0	-1470.
-0.	-477.	-0.	-0.	-0.	-0.	-0.	0.	-477.
-0.	4.	-0	-0	-0.	-0.	-0.	0.	4.
1	1302.	1	1.	1.	1.	1.	1.	1302.
1	1474	1	1	1	1	1.	1.	1474.

STRESSES(TXY, SX, SO, SY, SOCT, 2TMAX) VS (T, P, W, ZN, RO, MO, RN, MN, SUM) AT K = 6, U = 1., Y = 0.

0	224.	0.	0.	0.	0.	0.	-0.	224.
-0	50	-0.	-0.	-0	-0.	-0.	0.	50.
-0.	-45	-0	-0.	-0.	-0.	-0.	0.	-45.
-0.	28	-0	-0.	-0.	-0	-0.	0	28.
1.	397	1.	1.	1.	1.	1.	1.	397.
1.	448	1	1.	1	1.	1.	1	448.

STRESSES(TXY, SX, SO, SY, SOCT, 2TMAX) VS (T, P, W, ZN, RO, MO, RN, MN, SUM) AT K = 6, U = 1., Y = 0.0522

-0.	-0	-0	-0.	-0.	-0	-0.	0.	-0.
-0	1568.	-0.	-0	-0.	-0	-0.	0.	1568.
-0	425	-0	-0.	-0.	-0.	-0.	0.	425.
-0.	4.	-0	-0.	-0.	-0	-0	0.	4.
1	1401	1	1	1	1	1.	1.	1401.
1.	1564	1	1	1.	1.	1.	1.	1564.

STRESSES(TXY, SX, SO, SY, SOCT, 2TMAX) VS (T, P, W, ZN, RO, MO, RN, MN, SUM) AT K = 7, U = 0., Y = -0.0522

-0.	-0	-0	-0.	-0	-0.	-0.	0.	-0.
-0	-1498	-0	-0.	-0	-0	-0	0.	-1498.
-0.	-550.	-0	-0.	-0.	-0.	-0.	0.	-550.
-0	8	-0	-0.	-0	-0.	-0	0.	8.
1	1318.	1.	1.	1	1.	1.	1.	1318.
1	1506	1.	1	1	1.	1	1.	1506.

STRESSES(TXY, SX, SO, SY, SOCT, 2TMAX) VS (T, P, W, ZN, RO, MO, RN, MN, SUM) AT K = 7, U = 0., Y = 0.

0	224.	0.	0	0.	0	0.	-0.	224.
-0.	62.	-0	-0.	-0.	-0	-0.	0.	62.
-0	-108.	-0.	-0.	-0.	-0.	-0.	0.	-108.
-0.	56.	-0.	-0.	-0.	-0.	-0.	0.	56.
1.	422.	1.	1.	1.	1.	1.	1.	422.
1.	447.	1.	1.	1.	1.	1.	1.	447.

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STRESSES(TXY, SX, SO, SY, SOCT, 2TMAX) VS (T, P, W, ZN, RO, MO, RN, MN, SUM) AT K = 7, U = 0., Y = 0.0522

-0.	-0.	-0.	-0.	-0.	-0.	-0.	0.	-0.
-0.	1597.	-0.	-0.	-0.	-0.	-0.	0.	1597.
-0.	349.	-0.	-0.	-0.	-0.	-0.	0.	349.
-0.	8.	-0	-0.	-0.	-0.	-0.	0.	8.
1.	1449.	1.	1.	1.	1.	1.	1.	1449.
1.	1589.	1.	1.	1.	1.	1.	1.	1589.

STRESSES(TXY, SX, SO, SY, SOCT, 2TMAX) VS (T, P, W, ZN, RO, MO, RN, MN, SUM) AT K = 7, U = 1., Y = -0.0522

-0.	-0.	-0.	-0.	-0.	-0.	-0.	0.	-0.
-0.	-2285.	-0.	-0.	-0.	-0.	-0.	0.	-2285.
-0.	-124.	-0.	-0.	-0.	-0.	-0.	0.	-124.
-0.	8	-0.	-0.	-0.	-0.	-0.	0.	8.
1.	2230.	1.	1.	1.	1.	1.	1.	2230.
1.	2293.	1.	1.	1.	1.	1.	1.	2293.

STRESSES(TXY, SX, SO, SY, SOCT, 2TMAX) VS (T, P, W, ZN, RO, MO, RN, MN, SUM) AT K = 7, U = 1., Y = 0.

0.	169.	0.	0.	0.	0.	0.	-0.	169.
-0.	81.	-0	-0.	-0.	-0.	-0.	0.	81.
-0.	627.	-0.	-0.	-0.	-0.	-0.	0.	627.
-0.	56.	-0.	-0.	-0.	-0	-0.	0.	56.
1.	630.	1.	1.	1.	1.	1.	1.	630.
1.	727.	1.	1.	1.	1.	1.	1.	727.

STRESSES(TXY, SX, SO, SY, SOCT, 2TMAX) VS (T, P, W, ZN, RO, MO, RN, MN, SUM) AT K = 7, U = 1., Y = 0.0522

-0.	-0.	-0.	-0.	-0.	-0.	-0.	0.	-0.
-0.	2438.	-0	-0.	-0.	-0	-0.	0.	2438.
-0.	1445	-0	-0.	-0	-0.	-0.	0.	1445.
-0.	8.	-0	-0.	-0.	-0.	-0.	0.	8.
1.	2116.	1.	1.	1.	1.	1.	1.	2116.
1.	2430.	1.	1.	1.	1.	1.	1.	2430.

STRESSES(TXY, SX, SO, SY, SOCT, 2TMAX) VS (T, P, W, ZN, RO, MO, RN, MN, SUM) AT K = 8, U = 0., Y = -0.0522

-0.	-0.	-0.	-0	-0	-0.	-0.	0.	-0.
-0.	-2278.	-0.	-0.	-0	-0.	-0.	0.	-2278.
-0	-162.	-0	-0.	-0.	-0.	-0.	0.	-162.
-0.	11	-0.	-0.	-0.	-0.	-0.	0.	11.
1.	2207	1.	1.	1.	1.	1.	1.	2207.
1.	2289	1	1.	1.	1.	1.	1	2289.

STRESSES(TXY, SX, SO, SY, SOCT, 2TMAX) VS (T, P, W, ZN, RO, MO, RN, MN, SUM) AT K = 8, U = 0., Y = 0.

0.	169	0	0.	0.	0.	0.	-0.	169.
-0.	91.	-0	-0.	-0.	-0.	-0.	0.	91.
-0	591.	-0	-0.	-0	-0.	-0	0.	591.
-0.	80.	-0	-0.	-0	-0.	-0.	0	80.
1.	584.	1.	1.	1.	1.	1.	1.	584.
1.	674	1.	1.	1.	1.	1.	1.	674.

STRESSES(TXY, SX, SO, SY, SOCT, 2TMAX) VS (T, P, W, ZN, RO, MO, RN, MN, SUM) AT K = 8, U = 0., Y = 0.0522

-0.	-0.	-0.	-0.	-0.	-0	-0.	0.	-0.
-0.	2432.	-0.	-0.	-0.	-0.	-0.	0.	2432.
-0	1389.	-0.	-0.	-0.	-0.	-0.	0.	1389.
-0.	11.	-0.	-0.	-0.	-0.	-0.	0	11.
1.	2103.	1.	1.	1.	1.	1.	1.	2103.
1.	2420.	1.	1.	1.	1.	1.	1.	2420.

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STRESSES(TXY, SX, SO, SY, SOCT, 2TMAX) VS (T, P, W, ZN, RO, MO, RN, MN, SUM) AT K = 8, U = 1., Y = -0.0522

-0	-0	-0	-0.	-0.	-0.	-0	0.	-0.
-0.	-2487	-0.	-0.	-0.	-0	-0	0.	-2487.
-0.	326.	-0.	-0.	-0.	-0.	-0	0	326.
-0	11	-0.	-0.	-0.	-0	-0	0.	11.
1	2670.	1.	1.	1.	1.	1.	1.	2670.
1.	2814.	1.	1.	1	1	1.	1.	2814.

STRESSES(TXY, SX, SO, SY, SOCT, 2TMAX) VS (T, P, W, ZN, RO, MO, RN, MN, SUM) AT K = 8, U = 1., Y = 0.

0.	53.	0.	0.	0.	0.	0.	-0.	53.
-0	94	-0.	-0.	-0.	-0.	-0.	0	94.
-0.	1206	-0.	-0.	-0	-0	-0.	0.	1206.
-0	80.	-0.	-0.	-0.	-0.	-0	0.	80.
1.	1123.	1.	1	1.	1.	1.	1.	1123.
1.	1173.	1	1	1.	1.	1.	1.	1173.

STRESSES(TXY, SX, SO, SY, SOCT, 2TMAX) VS (T, P, W, ZN, RO, MO, RN, MN, SUM) AT K = 8, U = 1., Y = 0.0522

-0	-0.	-0.	-0.	-0	-0.	-0.	0	-0.
-0.	2656.	-0.	-0.	-0	-0.	-0.	0	2656.
-0	2157.	-0.	-0.	-0.	-0.	-0.	0.	2157.
-0.	11.	-0	-0	-0.	-0.	-0.	0.	11.
1.	2434	1	1	1.	1.	1.	1.	2434.
1	2645	1	1	1.	1.	1.	1.	2645.

STRESSES(TXY, SX, SO, SY, SOCT, 2TMAX) VS (T, P, W, ZN, RO, MO, RN, MN, SUM) AT K = 9, U = 0., Y = -0.0522

-0.	-0.	-0.	-0.	-0.	-0.	-0.	0.	-0.
-0	-2499	-0	-0.	-0.	-0	-0.	0.	-2499.
-0	317.	-0.	-0	-0	-0.	-0	0.	317.
-0	13	-0.	-0.	-0	-0.	-0.	0.	13.
1	2676	1	1	1	1.	1.	1.	2676.
1.	2815.	1	1.	1.	1.	1.	1.	2815.

STRESSES(TXY, SX, SO, SY, SOCT, 2TMAX) VS (T, P, W, ZN, RO, MO, RN, MN, SUM) AT K = 9, U = 0., Y = 0.

0.	53.	0.	0.	0.	0.	0.	-0.	53.
-0.	100.	-0	-0.	-0	-0.	-0.	0.	100.
-0.	1204	-0.	-0.	-0.	-0	-0.	0.	1204.
-0.	92.	-0.	-0.	-0.	-0.	-0.	0.	92.
1.	1112.	1	1	1.	1.	1	1.	1112.
1.	1162.	1.	1.	1.	1	1.	1.	1162.

STRESSES(TXY, SX, SO, SY, SOCT, 2TMAX) VS (T, P, W, ZN, RO, MO, RN, MN, SUM) AT K = 9, U = 0., Y = 0.0522

-0.	-0.	-0.	-0	-0.	-0.	-0.	0.	-0.
-0.	2669	-0.	-0.	-0	-0	-0.	0	2669.
-0.	2152	-0.	-0.	-0.	-0.	-0.	0.	2152.
-0.	13.	-0	-0.	-0.	-0	-0.	0.	13.
1.	2439	1	1.	1.	1.	1.	1.	2439.
1	2656	1.	1.	1.	1.	1.	1.	2656.

STRESSES(TXY, SX, SO, SY, SOCT, 2TMAX) VS (T, P, W, ZN, RO, MO, RN, MN, SUM) AT K = 9, U = 1., Y = -0.0522

-0	-0.	-0.	-0.	-0.	-0.	-0.	0.	-0.
-0.	-2407.	-0.	-0.	-0.	-0	-0.	0.	-2407.
-0	1059	-0.	-0.	-0.	-0.	-0.	0.	1059.
-0	13.	-0.	-0.	-0.	-0.	-0.	0.	13.
1	3080.	1.	1.	1.	1.	1.	1.	3080.
1.	3467.	1.	1.	1.	1.	1.	1.	3467.

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STRESSES(TXY, SX, SO, SY, SOCT, 2TMAX) VS (T, P, W, ZN, RO, MO, RN, MN, SUM) AT K = 9, U = 1., Y = 0.

0.	-155.	0.	0.	0.	0.	0.	-0.	-155.
-0.	95.	-0.	-0.	-0.	-0.	-0.	0.	95.
-0.	2006.	-0.	-0.	-0.	-0.	-0.	0.	2006.
-0	92.	-0	-0.	-0.	-0.	-0.	0.	92.
1.	1932.	1.	1.	1.	1.	1.	1.	1932.
1.	2068	1.	1.	1.	1.	1.	1.	2068.

STRESSES(TXY, SX, SO, SY, SOCT, 2TMAX) VS (T, P, W, ZN, RO, MO, RN, MN, SUM) AT K = 9, U = 1., Y = 0.0522

-0.	-0.	-0.	-0.	-0.	-0.	-0.	0.	-0.
-0.	2573.	-0.	-0.	-0.	-0.	-0.	0.	2573.
-0.	3032.	-0.	-0.	-0.	-0.	-0.	0.	3032.
-0	13.	-0.	-0.	-0.	-0.	-0.	0.	13.
1.	2818.	1.	1.	1.	1.	1.	1.	2818.
1	3019.	1	1.	1.	1.	1.	1.	3019.

STRESSES(TXY, SX, SO, SY, SOCT, 2TMAX) VS (T, P, W, ZN, RO, MO, RN, MN, SUM) AT K = 10, U = 0., Y = -0.0522

-0.	-0.	-0.	-0.	-0.	-0.	-0.	0.	-0.
-0.	-2422.	-0.	-0.	-0.	-0.	-0.	0.	-2422.
-0.	1083.	-0.	-0.	-0.	-0.	-0.	0.	1083.
-0.	13.	-0.	-0.	-0.	-0.	-0.	0.	13.
1.	3111.	1.	1.	1.	1.	1.	1.	3111.
1	3504.	1.	1.	1.	1.	1.	1.	3504.

STRESSES(TXY, SX, SO, SY, SOCT, 2TMAX) VS (T, P, W, ZN, RO, MO, RN, MN, SUM) AT K = 10, U = 0., Y = 0.

0.	-155.	0.	0.	0.	0.	0.	-0.	-155.
-0.	97	-0	-0	-0.	-0.	-0.	0	97.
-0.	2040	-0.	-0.	-0.	-0.	-0.	0.	2040.
-0.	96.	-0	-0.	-0.	-0.	-0.	0.	96.
1.	1962.	1.	1.	1.	1.	1	1.	1962.
1.	2099.	1.	1.	1.	1.	1.	1.	2099.

STRESSES(TXY, SX, SO, SY, SOCT, 2TMAX) VS (T, P, W, ZN, RO, MO, RN, MN, SUM) AT K = 10, U = 0., Y = 0.0522

-0.	-0.	-0.	-0.	-0.	-0.	-0.	0.	-0.
-0.	2589.	-0.	-0.	-0.	-0.	-0.	0.	2589.
-0.	3071.	-0.	-0.	-0.	-0.	-0.	0.	3071.
-0.	13.	-0.	-0.	-0.	-0.	-0.	0.	13.
1.	2848.	1.	1.	1.	1.	1.	1.	2848.
1.	3058.	1.	1.	1.	1.	1.	1.	3058.

STRESSES(TXY, SX, SO, SY, SOCT, 2TMAX) VS (T, P, W, ZN, RO, MO, RN, MN, SUM) AT K = 10, U = 1., Y = -0.0522

-0	-0	-0	-0	-0.	-0.	-0.	0.	-0.
-0.	-1830.	-0.	-0.	-0.	-0.	-0.	0.	-1830.
-0.	2127.	-0.	-0.	-0.	-0.	-0.	0.	2127.
-0.	13.	-0.	-0.	-0.	-0.	-0.	0.	13.
1.	3429.	1.	1.	1.	1.	1.	1.	3429.
1	3957	1.	1.	1.	1.	1.	1.	3957.

STRESSES(TXY, SX, SO, SY, SOCT, 2TMAX) VS (T, P, W, ZN, RO, MO, RN, MN, SUM) AT K = 10, U = 1., Y = 0.

0.	-486.	0.	0.	0.	0.	0.	-0.	-486.
-0	79.	-0.	-0.	-0.	-0.	-0.	0.	79.
-0	3016.	-0.	-0.	-0.	-0.	-0.	0.	3016.
-0.	96.	-0.	-0.	-0.	-0	-0.	0.	96.
1	3047.	1.	1.	1.	1.	1.	1.	3047.
1.	3414.	1.	1.	1.	1.	1.	1.	3414.

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STRESSES(TXY, SX, SO, SY, SOCT, 2TMAX) VS (T, P, W, ZN, RO, MO, RN, MN, SUM) AT K = 10, U = 1., Y = 0.0522

-0.	-0.	-0.	-0.	-0.	-0.	-0.	0.	-0.
-0.	1961.	-0.	-0.	-0.	-0.	-0.	0.	1961.
-0.	3982.	-0.	-0.	-0.	-0.	-0.	0	3982.
-0.	13	-0.	-0.	-0.	-0.	-0.	0.	13.
1.	3437.	1.	1.	1.	1.	1.	1.	3437.
1.	3969.	1.	1.	1.	1.	1.	1.	3969.

STRESSES(TXY, SX, SO, SY, SOCT, 2TMAX) VS (T, P, W, ZN, RO, MO, RN, MN, SUM) AT K = 11, U = 0., Y = -0.0522

-0.	-0.	-0.	-0.	-0.	-0.	-0.	0.	-0.
-0.	-1848	-0	-0.	-0.	-0.	-0.	0.	-1848.
-0	2202.	-0.	-0.	-0.	-0.	-0.	0.	2202.
-0.	11.	-0	-0	-0.	-0.	-0.	0.	11.
1	3511.	1.	1.	1.	1.	1.	1.	3511.
1.	4050.	1.	1.	1.	1.	1.	1.	4050.

STRESSES(TXY, SX, SO, SY, SOCT, 2TMAX) VS (T, P, W, ZN, RO, MO, RN, MN, SUM) AT K = 11, U = 0., Y = 0.

0.	-486.	0.	0.	0.	0.	0.	-0.	-486.
-0.	75.	-0.	-0.	-0.	-0.	-0.	0.	75.
-0.	3105.	-0.	-0.	-0.	-0.	-0.	0.	3105.
-0.	86	-0	-0.	-0.	-0.	-0.	0.	86.
1.	3139.	1.	1.	1.	1.	1.	1.	3139.
1	3510.	1	1.	1.	1	1.	1.	3510.

STRESSES(TXY, SX, SO, SY, SOCT, 2TMAX) VS (T, P, W, ZN, RO, MO, RN, MN, SUM) AT K = 11, U = 0., Y = 0.0522

-0	-0.	-0.	-0.	-0.	-0.	-0.	0.	-0.
-0.	1978.	-0.	-0.	-0.	-0.	-0.	0.	1978.
-0.	4091.	-0.	-0.	-0.	-0.	-0.	0.	4091.
-0	11.	-0.	-0.	-0	-0.	-0	0.	11.
1.	3533	1.	1.	1.	1.	1.	1.	3533.
1.	4079.	1.	1.	1.	1.	1.	1.	4079.

STRESSES(TXY, SX, SO, SY, SOCT, 2TMAX) VS (T, P, W, ZN, RO, MO, RN, MN, SUM) AT K = 11, U = 1., Y = -0.0522

-0	-0.	-0.	-0.	-0.	-0.	-0.	0.	-0.
-0.	-504	-0.	-0.	-0.	-0.	-0.	0.	-504.
-0.	3573	-0.	-0.	-0.	-0	-0	0.	3573.
-0.	11.	-0.	-0.	-0.	-0.	-0.	0.	11.
1.	3845.	1.	1.	1.	1.	1.	1.	3845.
1	4076.	1.	1.	1.	1.	1.	1.	4076.

STRESSES(TXY, SX, SO, SY, SOCT, 2TMAX) VS (T, P, W, ZN, RO, MO, RN, MN, SUM) AT K = 11, U = 1., Y = 0.

0.	-965.	0.	0.	0.	0.	0.	-0.	-965.
-0	37.	-0.	-0.	-0.	-0.	-0.	0.	37.
-0.	4202.	-0.	-0.	-0.	-0.	-0.	0.	4202.
-0.	86.	-0.	-0.	-0.	-0.	-0.	0.	86.
1.	4465	1.	1	1.	1.	1.	1.	4465.
1.	5105.	1.	1.	1.	1.	1.	1.	5105.

STRESSES(TXY, SX, SO, SY, SOCT, 2TMAX) VS (T, P, W, ZN, RO, MO, RN, MN, SUM) AT K = 11, U = 1., Y = 0.0522

-0.	-0.	-0.	-0.	-0.	-0.	-0.	0.	-0.
-0	551.	-0.	-0.	-0.	-0.	-0.	0.	551.
-0.	4888	-0.	-0.	-0.	-0.	-0.	0.	4888.
-0.	11.	-0	-0.	-0.	-0.	-0.	0.	11.
1.	4631.	1.	1.	1.	1.	1.	1.	4631.
1.	4877.	1.	1.	1.	1.	1.	1.	4877.

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STRESSES(TXY, SX, SO, SY, SOCT, 2TMAX) VS (T, P, W, ZN, RO, MO, RN, MN, SUM) AT K = 12, U = 0., V = -0.0522

-0.	0.	-0.	-0.	-0.	-0.	-0.	-0.	0.	0.
-0	-523.	-0.	-0.	-0.	-0.	-0.	-0.	0.	-523.
-0.	3724.	-0.	-0.	-0.	-0.	-0.	-0.	0.	3724.
-0.	6.	-0.	-0.	-0.	-0.	-0	-0.	0.	6.
1.	4009.	1.	1.	1.	1.	1.	1.	1.	4009.
1.	4247.	1.	1.	1	1	1.	1.	1.	4247.

STRESSES(TXY, SX, SO, SY, SOCT, 2TMAX) VS (T, P, W, ZN, RO, MO, RN, MN, SUM) AT K = 12, U = 0., V = 0.

0.	-965.	0.	0.	0.	0.	0.	0.	-0.	-965.
-0.	24.	-0.	-0.	-0.	-0.	-0.	-0.	0.	24.
-0	4369.	-0.	-0.	-0.	-0.	-0.	-0.	0.	4369.
-0.	52.	-0.	-0.	-0.	-0.	-0.	-0.	0.	52.
1.	4642.	1.	1.	1.	1.	1.	1.	1.	4642.
1.	5296.	1.	1.	1.	1.	1.	1.	1.	5296.

STRESSES(TXY, SX, SO, SY, SOCT, 2TMAX) VS (T, P, W, ZN, RO, MO, RN, MN, SUM) AT K = 12, U = 0., V = 0.0522

-0.	0.	-0.	-0.	-0.	-0.	-0.	-0.	0.	0.
-0.	568.	-0.	-0.	-0.	-0.	-0.	-0.	0.	568.
-0.	5096.	-0.	-0.	-0.	-0.	-0.	-0.	0.	5096.
-0.	6.	-0.	-0.	-0.	-0.	-0.	-0.	0.	6.
1.	4833.	1.	1.	1.	1.	1.	1.	1.	4833.
1.	5089.	1.	1.	1.	1.	1.	1.	1.	5089.

STRESSES(TXY, SX, SO, SY, SOCT, 2TMAX) VS (T, P, W, ZN, RO, MO, RN, MN, SUM) AT K = 12, U = 1., V = -0.0522

-0.	0.	-0.	-0.	-0.	-0.	-0.	-0.	0.	0.
-0	1869.	-0	-0.	-0.	-0	-0.	-0.	0.	1869.
-0.	5406.	-0.	-0.	-0.	-0.	-0.	-0.	0.	5406.
-0.	6.	-0.	-0	-0.	-0.	-0.	-0.	0.	6.
1.	4750.	1.	1.	1.	1.	1.	1.	1.	4750.
1.	5399.	1.	1.	1.	1.	1.	1.	1.	5399.

STRESSES(TXY, SX, SO, SY, SOCT, 2TMAX) VS (T, P, W, ZN, RO, MO, RN, MN, SUM) AT K = 12, U = 1., V = 0.

0.	-1613.	0.	0.	0.	0.	0.	0.	-0.	-1613.
-0.	-42.	-0.	-0.	-0.	-0.	-0.	-0.	0.	-42.
-0	5471.	-0.	-0.	-0.	-0.	-0.	-0.	0.	5471.
-0.	52.	-0.	-0.	-0.	-0.	-0.	-0.	0.	52.
1.	6139.	1.	1.	1.	1.	1.	1.	1.	6139.
1.	7079.	1.	1.	1.	1.	1.	1.	1.	7079.

STRESSES(TXY, SX, SO, SY, SOCT, 2TMAX) VS (T, P, W, ZN, RO, MO, RN, MN, SUM) AT K = 12, U = 1., V = 0.0522

-0.	0.	-0.	-0.	-0.	-0.	-0.	-0.	0.	0.
-0	-1975.	-0.	-0.	-0.	-0.	-0.	-0.	0.	-1975.
-0.	5552.	-0.	-0.	-0.	-0.	-0.	-0.	0.	5552.
-0.	6.	-0.	-0.	-0.	-0.	-0.	-0.	0.	6.
1.	6759.	1.	1.	1.	1.	1.	1.	1.	6759.
1.	7528.	1.	1.	1.	1.	1.	1.	1.	7528.

STRESSES(TXY, SX, SO, SY, SOCT, 2TMAX) VS (T, P, W, ZN, RO, MO, RN, MN, SUM) AT K = 13, U = 0., V = -0.0522

-0.	0.	-0.	-0.	-0.	-0.	-0.	-0.	0.	0.
-0.	1851.	-0.	-0.	-0.	-0.	-0.	-0.	0.	1851.
-0.	5661.	-0.	-0.	-0.	-0.	-0.	-0.	0.	5661.
-0.	-4.	-0.	-0.	-0.	-0.	-0.	-0.	0.	-4.
1.	5002.	1.	1.	1.	1.	1.	1.	1.	5002.
1.	5665.	1.	1.	1.	1.	1.	1.	1.	5665.

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STRESSES(TXY, SX, SO, SY, SOCT, 2TMAX) VS (T, P, W, ZN, RO, MO, RN, MN, SUM) AT K = 13, U = 0., Y = 0.

0.	-1613.	0.	0.	0.	0.	0.	-0.	-1613.
-0	-69.	-0.	-0.	-0.	-0.	-0.	0.	-69.
-0.	5742.	-0.	-0.	-0.	-0.	-0.	0.	5742.
-0	-15	-0.	-0.	-0.	-0.	-0.	0.	-15.
1.	6424.	1.	1.	1.	1.	1.	1.	6424.
1.	7397.	1.	1.	1.	1.	1.	1.	7397.

STRESSES(TXY, SX, SO, SY, SOCT, 2TMAX) VS (T, P, W, ZN, RO, MO, RN, MN, SUM) AT K = 13, U = 0., Y = 0.0522

-0	0.	-0.	-0.	-0.	-0.	-0.	0.	0.
-0	-1962	-0.	-0.	-0	-0.	-0.	0.	-1962.
-0	5892.	-0.	-0.	-0.	-0.	-0.	0.	5892.
-0.	-4.	-0.	-0.	-0.	-0.	-0.	0.	-4.
1.	7081.	1.	1.	1.	1.	1.	1.	7081.
1.	7854.	1	1.	1	1.	1.	1.	7854.

STRESSES(TXY, SX, SO, SY, SOCT, 2TMAX) VS (T, P, W, ZN, RO, MO, RN, MN, SUM) AT K = 13, U = 1., Y = -0.0522

-0.	0.	-0.	-0.	-0.	-0.	-0.	0.	0.
-0.	5608	-0.	-0.	-0	-0.	-0.	0.	5608.
-0.	7568.	-0.	-0.	-0.	-0.	-0.	0.	7568.
-0.	-4	-0.	-0.	-0.	-0.	-0.	0.	-4.
1.	6807	1.	1.	1.	1.	1.	1.	6807.
1	7572.	1	1	1	1.	1.	1.	7572.

STRESSES(TXY, SX, SO, SY, SOCT, 2TMAX) VS (T, P, W, ZN, RO, MO, RN, MN, SUM) AT K = 13, U = 1., Y = 0.

0.	-2432.	0.	0.	0.	0.	0.	-0.	-2432.
-0	-169.	-0	-0.	-0.	-0.	-0.	0.	-169.
-0	6653.	-0.	-0.	-0.	-0.	-0.	0.	6653.
-0	-15	-0.	-0.	-0.	-0.	-0.	0.	-15.
1.	7954.	1.	1.	1.	1.	1.	1.	7954.
1.	9179.	1.	1	1.	1	1.	1.	9179.

STRESSES(TXY, SX, SO, SY, SOCT, 2TMAX) VS (T, P, W, ZN, RO, MO, RN, MN, SUM) AT K = 13, U = 1., Y = 0.0522

-0.	0.	-0.	-0.	-0.	-0.	-0.	0.	0.
-0.	-5957.	-0.	-0.	-0.	-0.	-0.	0.	-5957.
-0.	5679.	-0.	-0.	-0.	-0.	-0.	0.	5679.
-0.	-4.	-0.	-0.	-0.	-0.	-0.	0	-4.
1.	10078.	1.	1.	1.	1.	1.	1.	10078.
1.	11636.	1	1.	1.	1.	1	1.	11636.

STRESSES(TXY, SX, SO, SY, SOCT, 2TMAX) VS (T, P, W, ZN, RO, MO, RN, MN, SUM) AT K = 14, U = 0., Y = -0.0522

-0.	0.	-0.	-0.	-0.	-0.	-0.	0.	0.
-0.	5686	-0.	-0.	-0.	-0.	-0.	0.	5686.
-0.	7887.	-0.	-0.	-0.	-0.	-0.	0.	7887.
-0.	-16	-0	-0.	-0	-0.	-0.	0.	-16.
1.	7065.	1.	1.	1.	1.	1.	1.	7065.
1.	7904.	1.	1.	1.	1.	1.	1.	7904.

STRESSES(TXY, SX, SO, SY, SOCT, 2TMAX) VS (T, P, W, ZN, RO, MO, RN, MN, SUM) AT K = 14, U = 0., Y = 0.

0.	-2432.	0.	0.	0.	0.	0.	-0.	-2432.
-0	208	-0	-0.	-0.	-0.	-0.	0.	-208.
-0.	6957.	-0.	-0.	-0.	-0.	-0.	0.	6957.
-0.	-100.	-0.	-0.	-0	-0.	-0.	0.	-100.
1.	8265.	1.	1.	1.	1.	1.	1.	8265.
1.	9543.	1.	1.	1.	1.	1.	1.	9543.

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STRESSES(TXY, SX, SO, SY, SOCT, 2TMAX) VS (T, P, W, ZN, RO, MO, RN, MN, SUM) AT K = 14, U = 0., Y = 0.0522

-0.	0.	-0.	-0.	-0.	-0.	-0.	-0.	0.	0.
-0.	-6050.	-0.	-0.	-0.	-0.	-0.	-0.	0.	-6050.
-0.	6031.	-0.	-0.	-0.	-0.	-0.	-0.	0.	6031.
-0.	-16.	-0.	-0.	-0.	-0.	-0.	-0.	0.	-16.
1.	10463.	1.	1.	1.	1.	1.	1.	1.	10463.
1	12081.	1.	1.	1.	1.	1	1.	1.	12081.

STRESSES(TXY, SX, SO, SY, SOCT, 2TMAX) VS (T, P, W, ZN, RO, MO, RN, MN, SUM) AT K = 14, U = 1., Y = -0.0522

-0.	0.	-0.	-0.	-0.	-0.	-0.	-0.	0.	0.
-0.	8719.	-0.	-0.	-0.	-0.	-0.	-0.	0.	8719.
-0.	9068.	-0.	-0.	-0.	-0.	-0.	-0.	0.	9068.
-0.	-16.	-0.	-0.	-0.	-0.	-0.	-0.	0.	-16.
1.	8915.	1.	1.	1.	1.	1.	1.	1.	8915.
1.	9084.	1.	1.	1.	1.	1.	1.	1.	9084.

STRESSES(TXY, SX, SO, SY, SOCT, 2TMAX) VS (T, P, W, ZN, RO, MO, RN, MN, SUM) AT K = 14, U = 1., Y = 0.

0.	-2996.	0.	0.	0.	0.	0.	0.	-0.	-2996.
-0.	-286.	-0.	-0.	-0.	-0.	-0.	-0.	0.	-286.
-0.	7290.	-0.	-0.	-0.	-0.	-0.	-0.	0.	7290.
-0.	-100.	-0.	-0.	-0.	-0.	-0.	-0.	0.	-100.
1.	9108.	1.	1.	1.	1.	1.	1.	1.	9108.
1.	10481.	1.	1.	1.	1.	1.	1.	1.	10481.

STRESSES(TXY, SX, SO, SY, SOCT, 2TMAX) VS (T, P, W, ZN, RO, MO, RN, MN, SUM) AT K = 14, U = 1., Y = 0.0522

-0.	0.	-0.	-0.	-0.	-0.	-0.	-0.	0.	0.
-0.	-9274	-0.	-0.	-0.	-0.	-0.	-0.	0.	-9274.
-0.	5404.	-0.	-0.	-0.	-0.	-0.	-0.	0	5404.
-0.	-16.	-0.	-0.	-0.	-0.	-0.	-0.	0.	-16.
1.	12855.	1.	1.	1.	1	1.	1.	1.	12855.
1.	14678.	1.	1.	1.	1	1.	1.	1.	14678.

STRESSES(TXY, SX, SO, SY, SOCT, 2TMAX) VS (T, P, W, ZN, RO, MO, RN, MN, SUM) AT K = 15, U = 0., Y = -0.0522

-0.	0.	-0.	-0.	-0.	-0.	-0.	-0.	0.	0.
0.	4353.	0	0.	0.	0.	0.	-0.		4353.
0.	7568.	0.	0.	0.	0.	0.	-0.		7568.
0.	0.	0.	0.	0.	0.	0.	-0.		0.
1.	6579.	1.	1.	1.	1.	1.	1.	1.	6579.
1.	7568.	1.	1.	1.	1.	1.	1.	1.	7568.

STRESSES(TXY, SX, SO, SY, SOCT, 2TMAX) VS (T, P, W, ZN, RO, MO, RN, MN, SUM) AT K = 15, U = 0., Y = 0.

0.	-2996.	0.	0.	0.	0.	0.	0.	-0.	-2996.
-0.	-93.	-0.	-0.	-0.	-0.	-0.	-0.	0.	-93.
-0.	1136.	-0.	-0.	-0.	-0.	-0.	-0.	0.	1136.
-0.	-21380	-0.	-0.	-0.	-0.	-0.	-0.	0.	-21380.
1.	22533.	1.	1.	1.	1.	1.	1.	1.	22533.
1.	22930.	1.	1.	1.	1.	1.	1.	1.	22930.

STRESSES(TXY, SX, SO, SY, SOCT, 2TMAX) VS (T, P, W, ZN, RO, MO, RN, MN, SUM) AT K = 15, U = 0., Y = 0.0522

-0	0.	-0.	-0.	-0.	-0.	-0.	0.	0.	0.
-0.	-5547.	-0.	-0.	-0.	-0.	-0.	-0.	0.	-5547.
-0.	-3837.	-0.	-0.	-0.	-0.	-0.	-0.	0.	-3837.
-0.	-47579.	-0.	-0.	-0.	-0.	-0.	-0.	0.	-47579.
1.	42913.	1.	1.	1.	1.	1.	1.	1.	42913.
1.	43742.	1.	1.	1.	1.	1.	1.	1.	43742.

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STRESSES(TXY, SX, SO, SY, SOCT, 2TMAX) VS (T, P, W, ZN, RO, MO, RN, MN, SUM) AT K = 15, U = 1., Y = -0.0522

-0	0.	-0	-0.	-0	-0	-0.	0.	0.
0.	4358.	0.	0.	0	0	0.	-0.	4358.
0.	7648.	0.	0.	0.	0.	0.	-0.	7648.
0.	0	0.	0.	0.	0.	0.	-0.	0.
1.	6645.	1.	1.	1.	1.	1.	1.	6645.
1	7648	1	1.	1.	1.	1.	1.	7648.

STRESSES(TXY, SX, SO, SY, SOCT, 2TMAX) VS (T, P, W, ZN, RO, MO, RN, MN, SUM) AT K = 15, U = 1., Y = 0.

0	2977.	0.	0.	0.	0.	0.	-0.	2977.
-0.	-93.	-0.	-0.	-0.	-0.	-0.	0.	-93.
-0.	1224.	-0.	-0.	-0.	-0.	-0.	0.	1224.
-0.	-21380.	-0.	-0.	-0	-0.	-0.	0.	-21380.
1.	22572.	1.	1.	1.	1.	1.	1.	22572.
1.	23013	1	1.	1.	1.	1.	1.	23013.

STRESSES(TXY, SX, SO, SY, SOCT, 2TMAX) VS (T, P, W, ZN, RO, MO, RN, MN, SUM) AT K = 15, U = 1., Y = 0.0522

-0.	0	-0	-0.	-0.	-0.	-0.	0.	0.
-0	-5552.	-0.	-0.	-0.	-0.	-0.	0.	-5552.
-0	-3739	-0	-0.	-0.	-0.	-0.	0.	-3739.
-0.	-47579	-0	-0.	-0.	-0.	-0.	0.	-47579.
1	42962	1.	1.	1	1.	1	1.	42962.
1	43840	1	1.	1.	1.	1.	1.	43840.

STRESSES(TXY, SX, SO, SY, SOCT, 2TMAX) VS (T, P, W, ZN, RO, MO, RN, MN, SUM) AT K = 16, U = 0., Y = -0.0522

-0.	0.	-0.	-0.	-0.	-0.	-0.	0.	0.
-0.	8560.	-0.	-0.	-0.	-0	-0.	0.	8560.
-0.	8988.	-0.	-0.	-0.	-0.	-0.	0.	8988.
-0.	-10	-0.	-0	-0.	-0	-0	0.	-10.
1.	8792.	1.	1.	1.	1.	1.	1.	8792.
1	8999	1.	1.	1	1.	1	1.	8999.

STRESSES(TXY, SX, SO, SY, SOCT, 2TMAX) VS (T, P, W, ZN, RO, MO, RN, MN, SUM) AT K = 16, U = 0., Y = 0.

0.	2977.	0.	0.	0	0.	0.	-0.	2977.
-0.	-266	-0.	-0	-0.	-0.	-0.	0.	-266.
-0.	7268	-0.	-0.	-0.	-0.	-0	0	7268.
-0.	-59.	-0	-0	-0.	-0.	-0.	0.	-59.
1.	9046.	1	1.	1.	1	1	1.	9046.
1.	10409	1.	1.	1.	1.	1.	1.	10409.

STRESSES(TXY, SX, SO, SY, SOCT, 2TMAX) VS (T, P, W, ZN, RO, MO, RN, MN, SUM) AT K = 16, U = 0., Y = 0.0522

-0.	0	-0.	-0.	-0.	-0.	-0.	0.	0.
-0	-9103.	-0.	-0.	-0.	-0	-0.	0.	-9103.
-0.	5412.	-0.	-0.	-0.	-0.	-0.	0.	5412.
-0.	-10	-0.	-0.	-0.	-0.	-0.	0.	-10.
1.	12703	1.	1	1.	1.	1.	1.	12703.
1.	14515.	1.	1	1	1	1.	1.	14515.

STRESSES(TXY, SX, SO, SY, SOCT, 2TMAX) VS (T, P, W, ZN, RO, MO, RN, MN, SUM) AT K = 16, U = 1., Y = -0.0522

-0	0.	-0.	-0.	-0.	-0.	-0.	0.	0.
-0	3223.	-0.	-0.	-0.	-0.	-0	0.	3223.
-0	7621	-0.	-0.	-0	-0.	-0.	0.	7621.
-0	-10	-0.	-0.	-0.	-0.	-0.	0.	-10.
1.	6635.	1.	1.	1.	1.	1.	1.	6635.
1.	7632	1.	1.	1.	1.	1	1.	7632.

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STRESSES(TXY, SX, SO, SY, SOCT, 2TMAX) VS (T, P, W, ZN, RO, MO, RN, MN, SUM) AT K = 16, U = 1., Y = 0.

0.	1803.	0.	0.	0.	0.	0.	-0.	1803.
-0.	-127.	-0	-0.	-0.	-0.	-0.	0.	-127.
-0.	7477.	-0.	-0.	-0.	-0.	-0.	0.	7477.
-0.	-59.	-0	-0.	-0.	-0.	-0.	0.	-59.
1.	8189.	1.	1.	1.	1.	1.	1.	8189.
1.	9373.	1.	1.	1.	1.	1.	1.	9373.

STRESSES(TXY, SX, SO, SY, SOCT, 2TMAX) VS (T, P, W, ZN, RO, MO, RN, MN, SUM) AT K = 16, U = 1., Y = 0.0522

-0.	0.	-0.	-0.	-0.	-0.	-0.	0.	0.
-0.	-3422.	-0.	-0.	-0.	-0.	-0.	0.	-3422.
-0	7421.	-0.	-0.	-0.	-0.	-0.	0.	7421.
-0.	-10.	-0.	-0.	-0.	-0.	-0.	0.	-10.
1.	9603.	1.	1.	1.	1.	1.	1.	9603.
1.	10843.	1.	1.	1.	1.	1.	1.	10843.

STRESSES(TXY, SX, SO, SY, SOCT, 2TMAX) VS (T, P, W, ZN, RO, MO, RN, MN, SUM) AT K = 17, U = 0., Y = -0.0522

-0.	0.	-0.	-0.	-0.	-0.	-0.	0.	0.
-0.	3292.	-0.	-0.	-0.	-0.	-0.	0.	3292.
-0.	7312.	-0.	-0.	-0.	-0.	-0.	0.	7312.
-0	5	-0.	-0.	-0.	-0.	-0.	0.	5.
1.	6339	1.	1.	1.	1.	1.	1.	6339.
1.	7308.	1.	1.	1.	1.	1.	1.	7308.

STRESSES(TXY, SX, SO, SY, SOCT, 2TMAX) VS (T, P, W, ZN, RO, MO, RN, MN, SUM) AT K = 17, U = 0., Y = 0.

0.	1803.	0.	0.	0.	0.	0.	-0.	1803.
-0.	-86	-0.	-0.	-0	-0.	-0.	0.	-86.
-0	7144.	-0	-0.	-0.	-0	-0.	0.	7144.
-0.	44	-0.	-0	-0.	-0.	-0.	0.	44.
1	7816	1	1.	1	1.	1.	1.	7816.
1.	8969.	1.	1.	1.	1.	1.	1.	8969.

STRESSES(TXY, SX, SO, SY, SOCT, 2TMAX) VS (T, P, W, ZN, RO, MO, RN, MN, SUM) AT K = 17, U = 0., Y = 0.0522

-0.	0.	-0.	-0.	-0	-0.	-0	0.	0.
-0.	-3488.	-0.	-0.	-0.	-0.	-0.	0.	-3488.
-0.	6976.	-0	-0.	-0.	-0.	-0.	0.	6976.
-0.	5	-0.	-0.	-0	-0.	-0.	0.	5.
1.	9227.	1.	1.	1.	1.	1.	1.	9227.
1.	10464.	1.	1.	1	1.	1.	1.	10464.

STRESSES(TXY, SX, SO, SY, SOCT, 2TMAX) VS (T, P, W, ZN, RO, MO, RN, MN, SUM) AT K = 17, U = 1., Y = -0.0522

-0.	0.	-0.	-0.	-0.	-0.	-0.	0.	0.
-0.	803.	-0	-0	-0.	-0.	-0	0.	803.
-0.	6411.	-0.	-0.	-0.	-0.	-0.	0.	6411.
-0.	5.	-0.	-0.	-0	-0.	-0.	0.	5.
1.	6047.	1	1.	1.	1.	1	1.	6047.
1.	6406	1.	1.	1.	1.	1.	1	6406.

STRESSES(TXY, SX, SO, SY, SOCT, 2TMAX) VS (T, P, W, ZN, RO, MO, RN, MN, SUM) AT K = 17, U = 1., Y = 0.

0.	874.	0.	0.	0.	0.	0.	-0.	874.
-0.	-21.	-0.	-0.	-0.	-0.	-0.	0.	-21.
-0	6946.	-0	-0.	-0.	-0.	-0.	0.	6946.
-0.	44.	-0	-0.	-0.	-0.	-0.	0.	44.
1.	7098.	1.	1.	1.	1.	1.	1.	7098.
1.	7809.	1.	1.	1.	1.	1.	1.	7809.

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STRESSES(TXY, SX, SO, SY, SOCT, 2TMAX) VS (T, P, W, ZN, RO, MO, RN, MN, SUM) AT K = 17, U = 1., Y = 0.0522

-0	0	-0.	-0	-0.	-0.	-0.	0.	0.	
-0.	-840.	-0	-0.	-0.	-0.	-0.	0.	-840.	
-0	7578.	-0.	-0.	-0.	-0.	-0.	0.	7578.	
-0.	5.	-0.	-0.	-0	-0.	-0.	0	5.	
1.	8029.	1.	1.	1.	1.	1.	1.	8029.	
1.	8418.	1	1	1.	1	1.	1.	8418.	

STRESSES(TXY, SX, SO, SY, SOCT, 2TMAX) VS (T, P, W, ZN, RO, MO, RN, MN, SUM) AT K = 18, U = 0., Y = -0.0522

-0	-0	-0	-0.	-0.	-0.	-0.	0.	0.	
-0.	809	-0.	-0.	-0.	-0.	-0.	0.	809.	
-0	6272.	-0.	-0.	-0	-0.	-0.	0.	6272.	
-0	10.	-0.	-0.	-0.	-0	-0.	0.	10.	
1.	5903	1.	1.	1.	1.	1.	1.	5903.	
1.	6262.	1.	1.	1.	1.	1.	1.	6262.	

STRESSES(TXY, SX, SO, SY, SOCT, 2TMAX) VS (T, P, W, ZN, RO, MO, RN, MN, SUM) AT K = 18, U = 0., Y = 0.

0.	874	0.	0.	0.	0.	0.	-0.	874.	
-0.	-4.	-0.	-0.	-0	-0.	-0	0.	-4.	
-0.	6802.	-0.	-0.	-0.	-0.	-0.	0.	6802.	
-0	85.	-0.	-0.	-0.	-0.	-0.	0.	85.	
1	6929.	1	1.	1.	1.	1.	1.	6929.	
1.	7637.	1.	1.	1.	1	1.	1.	7637.	

STRESSES(TXY, SX, SO, SY, SOCT, 2TMAX) VS (T, P, W, ZN, RO, MO, RN, MN, SUM) AT K = 18, U = 0., Y = 0.0522

-0.	-0.	-0.	-0.	-0.	-0.	-0.	0.	0.	
-0	-842	-0.	-0.	-0.	-0.	-0.	0	-842.	
-0	7396	-0	-0	-0	-0.	-0	0.	7396.	
-0	10	-0.	-0.	-0.	-0	-0	0.	10.	
1.	7847.	1	1.	1.	1.	1.	1.	7847.	
1.	8238.	1.	1.	1	1.	1.	1.	8238.	

STRESSES(TXY, SX, SO, SY, SOCT, 2TMAX) VS (T, P, W, ZN, RO, MO, RN, MN, SUM) AT K = 18, U = 1., Y = -0.0522

-0.	-0.	-0.	-0	-0.	-0	-0.	0.	0.	
-0	-3.	-0.	-0.	-0	-0.	-0.	0.	-3.	
-0.	5753	-0	-0.	-0.	-0.	-0.	0.	5753.	
-0.	10	-0	-0.	-0.	-0	-0.	0.	10.	
1	5749.	1.	1.	1.	1.	1.	1.	5749.	
1.	5756.	1.	1.	1	1.	1.	1.	5756.	

STRESSES(TXY, SX, SO, SY, SOCT, 2TMAX) VS (T, P, W, ZN, RO, MO, RN, MN, SUM) AT K = 18, U = 1., Y = 0.

0	0.	0.	0.	0.	0.	0.	-0.	-0.	
-0	18	-0.	-0.	-0.	-0.	-0.	0.	18.	
-0.	6485.	-0.	-0.	-0.	-0.	-0.	0.	6485.	
-0.	85.	-0.	-0.	-0.	-0.	-0.	0.	85.	
1.	6434.	1.	1.	1.	1.	1.	1.	6434.	
1.	6467	1.	1.	1.	1.	1.	1.	6467.	

STRESSES(TXY, SX, SO, SY, SOCT, 2TMAX) VS (T, P, W, ZN, RO, MO, RN, MN, SUM) AT K = 18, U = 1., Y = 0.0522

-0	-0.	-0.	-0.	-0.	-0.	-0.	0.	0.	
-0.	21	-0.	-0.	-0.	-0.	-0.	0.	21.	
-0	7307.	-0.	-0.	-0.	-0.	-0.	0	7307.	
-0	10.	-0.	-0.	-0.	-0.	-0.	0.	10.	
1.	7291.	1	1.	1.	1.	1.	1.	7291.	
1.	7296.	1.	1.	1.	1.	1.	1.	7296.	

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APPENDIX D

SAMPLE PRINTOUT, VIBRATION ANALYSIS CODES

The output forms included within this appendix concern the NASA vibration test model with the following characteristics

(1) Zero damping

(2) Spring constants = 30,000 lb/in

(3) Aluminum support tube end conditions are clamped at entrance end and simply supported at exit end

(4) Frequency = 59 8 cps

The results include the structural code UB012 at t = 0 167 second which indicates a stress of 35,340 psi at Station 35 0 This output corresponds with the results shown in Fig 43 of the report

```
START TIME 00 278 DATE  12/28/65 ID CARD *      FOR  06 S8038    02-121  4209-038-21691        SCHUMANN      8612  1
      REM     SAVE AND LABEL B5
      REM     THIS IS JOB NO  1
      REM     EST  RUN TIME 5
      REM     ************************************************************
      REM          TO INTERRUPT PROGRAM, DEPRESS SENSE SWITCH 5
      REM                        RESTART TAPE -- A5
      REM                   SCRATCH TAPES -- B2,B3,A4
      REM                BINARY INPUT DATA TAPE ON B5
      REM                S8038 PROGRAM TAPE (404) ON B9
      REM      IF TROUBLE, TRANSFER TO LOCATION 1 + SAVE RESTART TAPE
    *      XEQ
    *      NOMAP
     EXECUTION


                LINER MODEL NASA VIB  TEST K 30000 SIMP  SUP  ALUM  EXIT END

                                          I N P U T    D A T A

                   1   34    1    1
                  38   33   25    2        1       1

                                                                                                    PRINT I
                  18   12              38                                                         GP     0
                0 0                                                                 3             GP     1
                7 5                                                                 3             GP     2
                12 63                                                               3             GP     3
                22 0                                                                              GP     4
                24 01                                                               3             GP     5
                28 5                                                                              GP     6
                35 0                                                                              GP     7
                44 0                                                                              GP     8
                52 75                                                                             GP     9
                0 0             1 0                                         2       3             GP    10
                7 5             1 0                                         2                     GP    11
                12 63           1 0                                         2                     GP    12
                22 0            1 0                                         2                     GP    13
                24 01           1 0                                         2                     GP    14
                28 5            1 0                                         2                     GP    15
                35 0            1 0                                         2                     GP    16
                44 0            1 0                                         2                     GP    17
                52 75           1 0                                         2       3             GP    18
                END
                   2    1    2 23      1    1   10                                               T     1-2
                   2    2    3 23      1    1   10                                               T     3-4
                   2    3    4 2       1    1   10                                               T     5
                   3    3    4    5    1    1   10                                               T     6
                   2    4    5 3       1    1   10                                               T     7
                   2    5    6 2       1    1   10                                               T     8
                   3    5    6    7    1    1   10                                               T     9
                   3    6    7    8    1    1   10                                               T    10
                   3    7    8    9    1    1   10                                               T    11
                   2   10   11 2       1    1   10                                               T    12
                   3   10   11   12    1    1   10                                               T    13
                   3   11   12   13    1    1   10                                               T    14
                   3   12   13   14    1    1   10                                               T    15
                   3   13   14   15    1    1   10                                               T    16
                   3   14   15   16    1    1   10                                               T    17
                   3   15   16   17    1    1   10                                               T    18
                   3   16   17   18    1    1   10                                               T    19
                   2   17   18 3       1    1   10                                               T    20
                   2    1   10 6                                                                 T    21
                   2    9   18 6                                                                 T    22
                   2    1    2 6                                                                 T    23
                   2    2    3 6                                                                 T    24
                   2    3    4 6                                                                 T    25
                   2    4    5 6                                                                 T    26
                   2    5    6 6                                                                 T    27
                   2    6    7 6                                                                 T    28
                   2    7    8 6                                                                 T    29
                   2    8    9 6                                                                 T    30
                   2    4   13 6                                                          1      T    31
                   2    6   15 6                                                          1      T    32
                   2    7   16 6                                                          1      T    33
                   1   10    1   10                                         1 0                   T    34
```

```
LINER MODEL NASA VIB  TEST K 30000 SIMP  SUP  ALUM  EXIT END

                              I N P U T    D A T A

    1    1    1    2                                   1 0          T     35
    1   -1    1    2    1   10                                  I T     36
    1  -10    1    2    1   10                                      T     37
    1  -18    1    2   10    1                                  I T     38
END
   25    1         12                                                V      0
    1    1   10                                                     V      1
    2    1   10                                                     V      2
    3    1   10                                                     V      3
    4    1   10                                                     V      4
    5    1   10                                                     V      5
    6    1   10                                                     V      6
    7    1   10                                                     V      7
    8    1   10                                                     V      8
    9    1   10                                                     V      9
   11    1   10                                                     V     10
   12    1   10                                                     V     11
   13    1   10                                                     V     12
   14    1   10                                                     V     13
   15    1   10                                                     V     14
   16    1   10                                                     V     15
   17    1   10                                                     V     16
    1    1    2                                                     V     17
    2    1    2                                                     V     18
    3    1    2                                                     V     19
    4    1    2                                                     V     20
    5    1    2                                                     V     21
    6    1    2                                                     V     22
    7    1    2                                                     V     23
    8    1    2                                                     V     24
    9    1    2                                                     V     25
END
                                                                    NO TAU
                                                                    PRINT 2
-   1 65 46        -   2 65 46        -   3 4 68        -   4 4 68
-   5 7 86         -   6 7 86         -   7 7 86        -   8 9 876
-   9 9 876        -  10 9 876        -  11 9 876       -  12 10 26
-  13 10 26        -  14 10 26        -  15 10 26       -  16 10 26
-  17 10 26        -  18 10 26        -  19 10 26       -  20 10 26
-  23 37 43        -  24 2 80         -  25 4 7         -  26 4 7
-  27 5 9          -  28 5 9          -  29 5 9         -  30 5 9
-  31  030         -  32  030         -  33  030        -  34   10
-  35 1 0             38 100000 0
       1                1 0E06
-   1 130 92                                                        CC     2
            3                                                      CC     3
-   3 9 36                                                          CC     4
              5                                                    CC     5
-   5 15 72                                                         CC     6
K   6 15 72                                                        CC     7
              8                                                    CC     8
-   8 19 752                                                        CC     9
K   9 19 752                                                       CC    10
K  10 19 752                                                       CC    11
             12                                                    CC    12
-  12 20 52                                                        CC    13
K  13 20 52                                                        CC    14
K  14 20 52                                                        CC    15
K  15 20 52                                                        CC    16
K  16 20 52                                                        CC    17
K  17 20 52                                                        CC    18
K  18 20 52                                                        CC    19
K  19 20 52                                                        CC    20
             38                                                    CC    38
END
          1              1                                         PRINT  3
                                                                   NO THERM
       1  386 0                                                    MASS
1000 0                                                             M      1
2 34                                                               M      2
4 17                                                               M      3
3 35                                                               M      4
1 99                                                               M      5
3 41                                                               M      6
4 80                                                               M      7
5 53                                                               M      8
1000 0                                                             M      9
 28                                                                M     10
 33                                                                M     11
 26                                                                M     12
 15                                                                M     13
 25                                                                M     14
 36                                                                M     15
```

LINER MODEL NASA VIB TEST K 30000 SIMP SUP ALUM EXIT END

INPUT DATA

```
 39                                                          M   16
2000 0                                                       M   17
2 34                                                         M   18
4 17                                                         M   19
3 35                                                         M   20
1 99                                                         M   21
3 41                                                         M   22
4 80                                                         M   23
5 53                                                         M   24
 83                                                          M   25
END
```

LINER MODEL NASA VIB TEST K 30000 SIMP SUP ALUM EXIT END

GRID POINT CO-ORDINATES + THE PRIMARY EQUATIONS OF EQUILIBRIUM

```
GRID POINT   1  EQUATION   1  (1 2 0 3 0 0)    0                    -0                   -0
GRID POINT   2  EQUATION   4  (1 2 0 3 0 0)    7 50000000E 00       -0                   -0
GRID POINT   3  EQUATION   7  (1 2 0 3,0 0)    1 26299998E 01       -0                   -0
GRID POINT   4  EQUATION  10  (1,2 0 0 0 0)    2 19999999E 01       -0                   -0
GRID POINT   5  EQUATION  12  (1 2 0 3 0 0)    2 40099996E 01       -0                   -0
GRID POINT   6  EQUATION  15  (1 2,0 0 0 0)    2 84999996E 01       -0                   -0
GRID POINT   7  EQUATION  17  (1 2 0 0,0 0)    3 49999997E 01       -0                   -0
GRID POINT   8  EQUATION  19  (1 2 0 0 0 0)    4 39999998E 01       -0                   -0
GRID POINT   9  EQUATION  21  (1,2 0 0 0 0)    5 27499999E 01       -0                   -0
GRID POINT  10  EQUATION  23  (2 0 0 3,0 0)    0                    1 00000000E 00       -0
GRID POINT  11  EQUATION  25  (2 0 0,0 0 0)    7 50000000E 00       1 00000000E 00       -0
GRID POINT  12  EQUATION  26  (2 0 0 0 0 0)    1 26299998E 01       1 00000000E 00       -0
GRID POINT  13  EQUATION  27  (2,0 0 0 0 0)    2 19999999E 01       1 00000000E 00       -0
GRID POINT  14  EQUATION  28  (2 0 0 0 0 0)    2 40099996E 01       1 00000000E 00       -0
GRID POINT  15  EQUATION  29  (2,0 0 0,0 0)    2 84999996E 01       1 00000000E 00       -0
GRID POINT  16  EQUATION  30  (2,0,0 0 0 0)    3 49999997E 01       1 00000000E 00       -0
GRID POINT  17  EQUATION  31  (2 0 0 0 0 0)    4 39999998E 01       1 00000000E 00       -0
GRID POINT  18  EQUATION  32  (2 0 0 3 0 0)    5 27499998E 01       1 00000000E 00       -0
```

33 PRIMARY EQUATIONS OF EQUILIBRIUM HAVE BEEN SPECIFIED

LINER MODEL NASA VIB TEST K 30000 SIMP SUP ALUM EXIT END

EQUILIBRIUM MATRICES OF THE PRIMARY + REDUNDANT ELEMENTS

```
                                ELEMENT     1 ( PRIMARY )
TWO-DIGIT BENDING BETWEEN GRID POINTS   1 +    2 AT GRID POINT    1  IN THE +S DIRECTION
          ROW     1 = -0                        ROW     2 = -1 33333333E-01
                                ROW     3 = -1 00000000E 00
          ROW     4 =  0                        ROW     5 =  1 33333333E-01
                              ELEMENT  LENGTH = 7 50000000E 00

                                ELEMENT     2 ( PRIMARY )
TWO-DIGIT BENDING BETWEEN GRID POINTS   1 +    2 AT GRID POINT    2  IN THE -S DIRECTION
          ROW     1 =  0                        ROW     2 =  1 33333333E-01
          ROW     4 = -0                        ROW     5 = -1 33333333E-01
                                ROW     6 =  1 00000000E 00
                              ELEMENT  LENGTH = 7 50000000E 00

                                CLEMENT     3 ( PRIMARY )
TWO-DIGIT BENDING BETWEEN GRID POINTS   2 +    3 AT GRID POINT    2  IN THE +S DIRECTION
          ROW     4 = -0                        ROW     5 = -1 94931772E-01
                                ROW     6 = -1 00000000E 00
          ROW     7 =  0                        ROW     8 =  1 94931772E-01
                              ELEMENT  LENGTH = 5 13000000E 00
```

```
LINER MODEL NASA VIB  TEST K 30000 SIMP  SUP  ALUM  EXIT END

          EQUILIBRIUM MATRICES OF THE PRIMARY + REDUNDANT ELEMENTS

                              ELEMENT    4 ( PRIMARY )
 TWO-DIGIT BENDING BETWEEN GRID POINTS   2 +   3 AT GRID POINT   3  IN THE -S DIRECTION
                 ROW    4 =  0                    ROW    5 =  1 94931772E-01
                 ROW    7 = -0                    ROW    8 = -1 94931772E-01
                                 ROW    9 =  1 00000000E 00
                               ELEMENT  LENGTH = 5 13000000E 00

                              ELEMENT    5 ( PRIMARY )
 TWO-DIGIT BENDING BETWEEN GRID POINTS   3 +   4 AT GRID POINT   3  IN THE +S DIRECTION
                 ROW    7 = -0                    ROW    8 = -1 06723584E-01
                                 ROW    9 = -1 00000000E 00
                 ROW   10 =  0                    ROW   11 =  1 06723584E-01
                               ELEMENT  LENGTH = 9 37000000E 00

                              ELEMENT    6 ( PRIMARY )
                        THREE-DIGIT BENDING AT GRID POINTS   3,   4,   5
                 ROW    7 =  0                    ROW    8 =  1 06723584E-01
                 ROW   10 = -0                    ROW   11 = -6 04236019E-01
                 ROW   12 =  0                    ROW   13 =  4 97512436E-01
 ELEMENT LENGTHS = 9 37000000E 00 + 2 00999999E 00          ELEMENT ANGLE =  1 79999994E 02

                              ELEMENT    7 ( PRIMARY )
 TWO-DIGIT BENDING BETWEEN GRID POINTS   4 +   5 AT GRID POINT   5  IN THE -S DIRECTION
                 ROW   10 =  0                    ROW   11 =  4 97512436E-01
                 ROW   12 = -0                    ROW   13 = -4 97512436E-01
                                 ROW   14 =  1 00000000E 00
                               ELEMENT  LENGTH = 2 00999999E 00

                              ELEMENT    8 ( PRIMARY )
 TWO-DIGIT BENDING BETWEEN GRID POINTS   5 +   6 AT GRID POINT   5  IN THE +S DIRECTION
                 ROW   12 = -0                    ROW   13 = -2 22717145E-01
                                 ROW   14 = -1 00000000E 00
                 ROW   15 =  0                    ROW   16 =  2 22717145E-01
                               ELEMENT  LENGTH = 4 49000001E 00
                              ELEMENT    9 ( PRIMARY )
                        THREE-DIGIT BENDING AT GRID POINTS   5,   6,   7
                 ROW   12 =  0                    ROW   13 =  2 22717145E-01
                 ROW   15 = -0                    ROW   16 = -3 76563299E-01
                 ROW   17 =  0                    ROW   18 =  1 53846152E-01
 ELEMENT LENGTHS = 4 49000001E 00 + 6 50000000E 00          ELEMENT ANGLE =  1 79999994E 02

                              ELEMENT   10 ( PRIMARY )
                        THREE-DIGIT BENDING AT GRID POINTS   6,   7,   8
                 ROW   15 =  0                    ROW   16 =  1 53846152E-01
                 ROW   17 = -0                    ROW   18 = -2 64957258E-01
                 ROW   19 =  0                    ROW   20 =  1 11111110E-01
 ELEMENT LENGTHS = 6 50000000E 00 + 9 00000000E 00          ELEMENT ANGLE =  1 79999994E 02

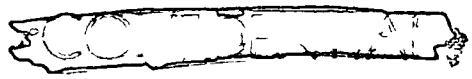
                              ELEMENT   11 ( PRIMARY )
                        THREE-DIGIT BENDING AT GRID POINTS   7,   8,   9
                 ROW   17 =  0                    ROW   18 =  1 11111110E-01
                 ROW   19 = -0                    ROW   20 = -2 25396824E-01
                 ROW   21 =  0                    ROW   22 =  1 14285713E-01
 ELEMENT LENGTHS = 9 00000000E 00 + 8 75000000E 00          ELEMENT ANGLE =  1 79999994E 02

                              ELEMENT   12 ( PRIMARY )
 TWO-DIGIT BENDING BETWEEN GRID POINTS  10 +  11 AT GRID POINT  10  IN THE +S DIRECTION
                                 ROW   23 = -1 33333333E-01
                                 ROW   24 = -1 00000000E 00
                                 ROW   25 =  1 33333333E-01
                               ELEMENT  LENGTH = 7 50000000E 00

                              ELEMENT   13 ( PRIMARY )
                        THREE-DIGIT BENDING AT GRID POINTS  10,  11,  12
                                 ROW   24 =  1 33333333E-01
                                 ROW   25 = -3 28265104E-01
                                 ROW   26 =  1 94931772E-01
 ELEMENT LENGTHS = 7 50000000E 00 + 5 13000000E 00          ELEMENT ANGLE =  1 79999994E 02

                              ELEMENT   14 ( PRIMARY )
                        THREE-DIGIT BENDING AT GRID POINTS  11,  12,  13
                                 ROW   25 =  1 94931772E-01
                                 ROW   26 = -3 01655355E-01
                                 ROW   27 =  1 06723584E-01
 ELEMENT LENGTHS = 5 13000000E 00 + 9 37000000E 00          ELEMENT ANGLE =  1 79999994E 02

                              ELEMENT   15 ( PRIMARY )
                        THREE-DIGIT BENDING AT GRID POINTS  12,  13,  14
                                 ROW   26 =  1 06723584E-01
                                 ROW   27 = -6 04236019E-01
                                 ROW   28 =  4 97512436E-01
 ELEMENT LENGTHS = 9 37000000E 00 + 2 00999999E 00          ELEMENT ANGLE =  1 79999994E 02
```



```
LINER MODEL NASA VIB  TEST K 30000 SIMP  SUP  ALUM  EXIT END

        EQUILIBRIUM MATRICES OF THE PRIMARY + REDUNDANT ELEMENTS

                              ELEMENT   16 ( PRIMARY )
                THREE-DIGIT BENDING AT GRID POINTS  13,  14,  15
                              ROW   27 =  4 97512436E-01
                              ROW   28 = -7 20229578E-01
                              ROW   29 =  2 22717145E-01
ELEMENT LENGTHS = 2 00999999E 00 + 4 49000001E 00          ELEMENT ANGLE =  1 79999994E 02


                              ELEMENT   17 ( PRIMARY )
                THREE-DIGIT BENDING AT GRID POINTS  14,  15,  16
                              ROW   28 =  2 22717145E-01
                              ROW   29 = -3 76563299E-01
                              ROW   30 =  1 53846152E-01
ELEMENT LENGTHS = 4 49000001E 00 + 6 50000000E 00          ELEMENT ANGLE =  1 79999994E 02

                              ELEMENT   18 ( PRIMARY )
                THREE-DIGIT BENDING AT GRID POINTS  15,  16,  17
                              ROW   29 =  1 53846152E-01
                              ROW   30 = -2 64957258E-01
                              ROW   31 =  1 11111110E-01
ELEMENT LENGTHS = 6 50000000E 00 + 9 00000000E 00          ELEMENT ANGLE =  1 79999994E 02

                              ELEMENT   19 ( PRIMARY )
                THREE-DIGIT BENDING AT GRID POINTS  16,  17,  18
                              ROW   30 =  1 11111110E-01
                              ROW   31 = -2 25396824E-01
                              ROW   32 =  1 14285713E-01
ELEMENT LENGTHS = 9 00000000E 00 + 8 75000000E 00          ELEMENT ANGLE =  1 79999994E 02

                              ELEMENT   20 ( PRIMARY )
  TWO-DIGIT BENDING BETWEEN GRID POINTS  17 +  18 AT GRID POINT  18  IN THE -S DIRECTION
                              ROW   31 =  1 14285713E-01
                              ROW   32 = -1 14285713E-01
                              ROW   33 =  1 00000000E 00
                            ELEMENT  LENGTH = 8 75000000E 00

                              ELEMENT   21 ( PRIMARY )
                            TENSION AT GRID POINTS   1 +  10
          ROW    1 =  0                          ROW    2 =  1 00000000E 00
                              ROW   23 = -1 00000000E 00
                            ELEMENT  LENGTH = 1 00000000E 00

                              ELEMENT   22 ( PRIMARY )
                            TENSION AT GRID POINTS   9 +  18
          ROW   21 =  0                          ROW   22 =  1 00000000E 00
                              ROW   32 = -1 00000000E 00
                            ELEMENT  LENGTH = 1 00000000E 00

                              ELEMENT   23 ( PRIMARY )
                            TENSION AT GRID POINTS   1 +   2
          ROW    1 =  1 00000000E 00          ROW    2 = -0
          ROW    4 = -1 00000000E 00          ROW    5 =  0
                            ELEMENT  LENGTH = 7 50000000E 00

                              ELEMENT   24 ( PRIMARY )
                            TENSION AT GRID POINTS   2 +   3
          ROW    4 =  1 00000000E 00          ROW    5 = -0
          ROW    7 = -1 00000000E 00          ROW    8 =  0
                            ELEMENT  LENGTH = 5 13000000E 00
                              ELEMENT   25 ( PRIMARY )
                            TENSION AT GRID POINTS   3 +   4
          ROW    7 =  1 00000000E 00          ROW    8 = -0
          ROW   10 = -1 00000000E 00          ROW   11 =  0
                            ELEMENT  LENGTH = 9 37000000F 00

                              ELEMENT   26 ( PRIMARY )
                            TENSION AT GRID POINTS   4 +   5
          ROW   10 =  1 00000000E 00          ROW   11 = -0
          ROW   12 = -1 00000000E 00          ROW   13 =  0
                            ELEMENT  LENGTH = 2 00999999E 00

                              ELEMENT   27 ( PRIMARY )
                            TENSION AT GRID POINTS   5 +   6
          ROW   12 =  1 00000000E 00          ROW   13 = -0
          ROW   15 = -1 00000000E 00          ROW   16 =  0
                            ELEMENT  LENGTH = 4 49000001E 00

                              ELEMENT   28 ( PRIMARY )
                            TENSION AT GRID POINTS   6 +   7
          ROW   15 =  1 00000000E 00          ROW   16 = -0
          ROW   17 = -1 00000000E 00          ROW   18 =  0
                            ELEMENT  LENGTH = 6 50000000E 00
```

LINER MODEL NASA VIB TEST K 30000 SIMP SUP ALUM EXIT END

EQUILIBRIUM MATRICES OF THE PRIMARY + REDUNDANT ELEMENTS

ELEMENT 29 (PRIMARY)
TENSION AT GRID POINTS 7 + 8
ROW 17 = 1 00000000E 00 ROW 18 = -0
ROW 19 = -1 00000000E 00 ROW 20 = 0
ELEMENT LENGTH = 9 00000000E 00

ELEMENT 30 (PRIMARY)
TENSION AT GRID POINTS 8 + 9
ROW 19 = 1 00000000E 00 ROW 20 = -0
ROW 21 = -1 00000000E 00 ROW 22 = 0
ELEMENT LENGTH = 8 75000000E 00

ELEMENT 31 (REDUNDANT)
TENSION AT GRID POINTS 4 + 13
ROW 10 = 0 ROW 11 = 1 00000000E 00
ROW 27 = -1 00000000E 00
ELEMENT LENGTH = 1 00000000E 00

ELEMENT 32 (REDUNDANT)
TENSION AT GRID POINTS 6 + 15
ROW 15 = 0 ROW 16 = 1 00000000E 00
ROW 29 = -1 00000000E 00
ELEMENT LENGTH = 1 00000000E 00

ELEMENT 33 (REDUNDANT)
TENSION AT GRID POINTS 7 + 16
ROW 17 = 0 ROW 18 = 1 00000000E 00
ROW 30 = -1 00000000E 00
ELEMENT LENGTH = 1 00000000E 00

ELEMENT 34 (PRIMARY)
AXIAL REACTION AT GRID POINT 10
ROW 23 = 1 00000000E 00
REACTION LENGTH = 1 00000000E 00

ELEMENT 35 (PRIMARY)
AXIAL REACTION AT GRID POINT 1
ROW 1 = 1 00000000E 00 ROW 2 = -0
REACTION LENGTH = 1 00000000E 00

ELEMENT 36 (REDUNDANT)
MOMENT REACTION AT GRID POINT 1
ROW 3 = 1 00000000E 00

ELEMENT 37 (PRIMARY)
MOMENT REACTION AT GRID POINT 10
ROW 24 = 1 00000000E 00

ELEMENT 38 (REDUNDANT)
MOMENT REACTION AT GRID POINT 18
ROW 33 = -1 00000000E 00

33 PRIMARY ELEMENTS AND 5 REDUNDANT ELEMENTS HAVE BEEN SPECIFIED

LINER MODEL NASA VIB TEST K 30000 SIMP SUP ALUM EXIT END

INVERSION CHECK FOR THE T(T) MATRIX

-1 00000000E 00	-9 99999988E-01	-1 00000000E 00	-1 00000000E 00	-9 99999988E-01	-1 00000000E 00	6
-9 99999988E-01	-9 99999988E-01	-1 00000000E 00	-9 99999988E-01	-9 99999988E-01	-1 00000000E 00	12
-1 00000000E 00	-1 00000000E 00	-1 00000000E 00	-1 00000000E 00	-1 00000000E 00	-1 00000000E 00	18
-1 00000000E 00	-1 00000000E 00	-1 00000000E 00	-1 00000000E 00	-1 00000000E 00	-1 00000000E 00	24
-1 00000000E 00	-1 00000000E 00	-1 00000000E 00	-1 00000000E 00	-1 00000000E 00	-1 00000000E 00	30
-1 00000000E 00	-1 00000000E 00	-1 00000000E 00				33

DETERMINANT = 1 90183680E-11

LINER MODEL NASA VI8 TEST K 30000 SIMP SUP ALUM EXIT END

EQUILIBRIUM MATRIX OF EXTERNALLY APPLIED UNIT LOADS DEFINING THE DEGREES OF FREEDOM

GRID POINT 1, DEGREES OF FREEDOM 1 - 1, (1,0,0,0,0,0)
UNIT LOADS
ROW 1 = 0 ROW 2 = 1 00000000E 00
INITIAL FREE-FREE TRANSFORMATIONS
0 1 00000000E 00

GRID POINT 2 DEGREES OF FREEDOM 2 - 2, (1,0,0,0,0,0)
UNIT LOADS
ROW 4 = 0 ROW 5 = 1 00000000E 00
INITIAL FREE-FREE TRANSFORMATIONS
0 1 00000000E 00

GRID POINT 3, DEGREES OF FREEDOM 3 - 3, (1,0,0,0,0,0)
UNIT LOADS
ROW 7 = 0 ROW 8 = 1 00000000E 00
INITIAL FREE-FREE TRANSFORMATIONS
0 1 00000000E 00

GRID POINT 4, DEGREES OF FREEDOM 4 - 4, (1,0,0,0,0,0)
UNIT LOADS
ROW 10 = 0 ROW 11 = 1 00000000E 00
INITIAL FREE-FREE TRANSFORMATIONS
0 1 00000000E 00

GRID POINT 5 DEGREES OF FREEDOM 5 - 5, (1,0,0,0,0,0)
UNIT LOADS
ROW 12 = 0 ROW 13 = 1 00000000E 00
INITIAL FREE-FREE TRANSFORMATIONS
0 1 00000000E 00

GRID POINT 6 DEGREES OF FREEDOM 6 - 6, (1,0,0,0,0,0)
UNIT LOADS
ROW 15 = 0 ROW 16 = 1 00000000E 00
INITIAL FREE-FREE TRANSFORMATIONS
0 1 00000000E 00

GRID POINT 7, DEGREES OF FREEDOM 7 - 7, (1,0,0,0,0,0)
UNIT LOADS
ROW 17 = 0 ROW 18 = 1 00000000E 00
INITIAL FREE-FREE TRANSFORMATIONS
0 1 00000000E 00

GRID POINT 8, DEGREES OF FREEDOM 8 - 8, (1,0,0,0,0,0)
UNIT LOADS
ROW 19 = 0 ROW 20 = 1 00000000E 00
INITIAL FREE-FREE TRANSFORMATIONS
0 1 00000000E 00

GRID POINT 9, DEGREES OF FREEDOM 9 - 9, (1,0,0,0,0,0)
UNIT LOADS
ROW 21 = 0 ROW 22 = 1 00000000E 00
INITIAL FREE-FREE TRANSFORMATIONS
0 1 00000000E 00

GRID POINT 11, DEGREES OF FREEDOM 10 - 10, (1,0,0,0,0,0)
UNIT LOADS
ROW 25 = 1 00000000E 00
INITIAL FREE-FREE TRANSFORMATIONS
0 1 00000000E 00

GRID POINT 12, DEGREES OF FREEDOM 11 - 11, (1,0,0,0,0,0)
UNIT LOADS
ROW 26 = 1 00000000E 00
INITIAL FREE-FREE TRANSFORMATIONS
0 1 00000000E 00

GRID POINT 13, DEGREES OF FREEDOM 12 - 12, (1,0,0,0,0,0)
UNIT LOADS
ROW 27 = 1 00000000E 00
INITIAL FREE-FREE TRANSFORMATIONS
0 1 00000000E 00

GRID POINT 14 DEGREES OF FREEDOM 13 - 13, (1,0,0,0,0,0)
UNIT LOADS
ROW 28 = 1 00000000E 00
INITIAL FREE-FREE TRANSFORMATIONS
0 1 00000000E 00

GRID POINT 15, DEGREES OF FREEDOM 14 - 14, (1,0,0,0,0,0)
UNIT LOADS
ROW 29 = 1 00000000E 00
INITIAL FREE-FREE TRANSFORMATIONS
0 1 00000000E 00

LINER MODEL NASA VIB TEST K 30000 SIMP SUP ALUM EXIT END

EQUILIBRIUM MATRIX OF EXTERNALLY APPLIED UNIT LOADS DEFINING THE DEGREES OF FREEDOM

GRID POINT 16 DEGREES OF FREEDOM 15 - 15, (1,0,0,0,0,0)
UNIT LOADS
ROW 30 = 1.00000000E 00
INITIAL FREE-FREE TRANSFORMATIONS
0 1.00000000E 00

GRID POINT 17 DEGREES OF FREEDOM 16 - 16, (1,0,0,0,0,0)
UNIT LOADS
ROW 31 = 1.00000000E 00
INITIAL FREE-FREE TRANSFORMATIONS
0 1.00000000E 00

GRID POINT 1 DEGREES OF FREEDOM 17 - 17, (1,0,0,0,0,0)
UNIT LOADS
ROW 1 = 1.00000000E 00 ROW 2 = -0
INITIAL FREE-FREE TRANSFORMATIONS
1.00000000E 00 -0

GRID POINT 2 DEGREES OF FREEDOM 18 - 18, (1,0,0,0,0,0)
UNIT LOADS
ROW 4 = 1.00000000E 00 ROW 5 = -0
INITIAL FREE-FREE TRANSFORMATIONS
1.00000000E 00 -0

GRID POINT 3 DEGREES OF FREEDOM 19 - 19, (1,0,0,0,0,0)
UNIT LOADS
ROW 7 = 1.00000000E 00 ROW 8 = -0
INITIAL FREE-FREE TRANSFORMATIONS
1.00000000E 00 -0

GRID POINT 4 DEGREES OF FREEDOM 20 - 20, (1,0,0,0,0,0)
UNIT LOADS
ROW 10 = 1.00000000E 00 ROW 11 = -0
INITIAL FREE-FREE TRANSFORMATIONS
1.00000000E 00 -0

GRID POINT 5 DEGREES OF FREEDOM 21 - 21 (1,0,0,0,0,0)
UNIT LOADS
ROW 12 = 1.00000000E 00 ROW 13 = -0
INITIAL FREE-FREE TRANSFORMATIONS
1.00000000E 00 -0

GRID POINT 6, DEGREES OF FREEDOM 22 - 22, (1,0,0,0,0,0)
UNIT LOADS
ROW 15 = 1.00000000E 00 ROW 16 = -0
INITIAL FREE-FREE TRANSFORMATIONS
1.00000000E 00 -0

GRID POINT 7, DEGREES OF FREEDOM 23 - 23, (1,0,0,0,0,0)
UNIT LOADS
ROW 17 = 1.00000000E 00 ROW 18 = -0
INITIAL FREE-FREE TRANSFORMATIONS
1.00000000E 00 -0

GRID POINT 8, DEGREES OF FREEDOM 24 - 24, (1,0,0,0,0,0)
UNIT LOADS
ROW 19 = 1.00000000E 00 ROW 20 = -0
INITIAL FREE-FREE TRANSFORMATIONS
1.00000000E 00 -0

GRID POINT 9, DEGREES OF FREEDOM 25 - 25, (1,0,0,0,0,0)
UNIT LOADS
ROW 21 = 1.00000000E 00 ROW 22 = -0
INITIAL FREE-FREE TRANSFORMATIONS
1.00000000E 00 -0

25 DEGREES OF FREEDOM HAVE BEEN SPECIFIED
2 RIGID BODY CONSTRAINTS WERE INDICATED - (1,2,0,0,0,0)

LINER MODEL NASA VIB TEST K 30000 SIMP SUP ALUM EXIT END

COMPLIANCE MATRIX ASSEMBLY
(UNCOUPLED COMPLIANCES)

1 14573786E-07	1 14573786E-07	1 09615384E-06	1 09615384E-06	1 19211194E-06	1 44783713E-06	6
2 55725184E-07	4 54637504E-07	1 11279869E-06	1 56946132E-06	1 79728635E-06	7 30994141E-07	12
1 23099414E-06	1 41325533E-06	1 10916176E-06	6 33528256E-07	1 07115008E-06	1 51072122E-06	18
1 73001947E-06	8 52826500E-07	0	0	2.00374028E-07	1 83214284E-06	24
1 99361698E-06	4 27659565E-07	7 61016947E-07	1 10169490E-06	1 52542371E-06	1 48305084E-06	30
3 33333331E-05	3 33333331E-05	3 33333331E-05	0 99999999E-05	0 99999999E-06	0	36
0	0 99999999E-01					38

LINER MODEL NASA VIB TEST K 30000 SIMP SUP ALUM EXIT END

COMPLIANCE MATRIX ASSEMBLY

COUPLING OF ELEMENT 1
ELEMNT 1 = 1 14573786E-07 ELEMNT 2 = 5 72868931E-08

COUPLING OF ELEMENT 2
ELEMNT 1 = 5 72868931E-08 ELEMNT 2 = 1 14573786E-07

COUPLING OF ELEMENT 3
ELEMNT 3 = 1 09615384E-06 ELEMNT 4 = 5 48076922E-07

COUPLING OF ELEMENT 4
ELEMNT 3 = 5 48076922E-07 ELEMNT 4 = 1 09615384E-06

COUPLING OF ELEMENT 5
ELEMNT 5 = 1 19211194E-06 ELEMNT 6 = 5 96055973E-07

COUPLING OF ELEMENT 6
ELEMNT 5 = 5 96055973E-07 ELEMNT 6 = 1 44783713E-06 ELEMNT 7 = 1 27862592E-07

COUPLING OF ELEMENT 7
ELEMNT 6 = 1 27862592E-07 ELEMNT 7 = 2 55725184E-07

COUPLING OF ELEMENT 8
ELEMNT 8 = 4 54637504E-07 ELEMNT 9 = 2 27318752E-07

COUPLING OF ELEMENT 9
ELEMNT 8 = 2 27318752E-07 ELEMNT 9 = 1 11279869E-06 ELEMNT 10 = 3 29080597E-07

COUPLING OF ELEMENT 10
ELEMNT 9 = 3 29080597E-07 ELEMNT 10 = 1 56946132E-06 ELEMNT 11 = 4 55650055E-07

COUPLING OF ELEMENT 11
ELEMNT 10 = 4 55650055E-07 ELEMNT 11 = 1 79728635E-06

COUPLING OF ELEMENT 12
ELEMNT 12 = 7 30994141E-07 ELEMNT 13 = 3 65497071E-07

COUPLING OF ELEMENT 13
ELEMNT 12 = 3 65497071E-07 ELEMNT 13 = 1 23099414E-06 ELEMNT 14 = 2 49999997E-07

COUPLING OF ELEMENT 14
ELEMNT 13 = 2 49999997E-07 ELEMNT 14 = 1 41325533E-06 ELEMNT 15 = 4 56627673E-07

COUPLING OF ELEMENT 15
ELEMNT 14 = 4 56627673E-07 ELEMNT 15 = 1 10916176E-06 ELEMNT 16 = 9 79532135E-08

COUPLING OF ELEMENT 16
ELEMNT 15 = 9 79532135E-08 ELEMNT 16 = 6 33528256E-07 ELEMNT 17 = 2 18810913E-07

COUPLING OF ELEMENT 17
ELEMNT 16 = 2 18810913E-07 ELEMNT 17 = 1 07115008E-06 ELEMNT 18 = 3 16764128E-07

COUPLING OF ELEMENT 18
ELEMNT 17 = 3 16764128E-07 ELEMNT 18 = 1 51072122E-06 ELEMNT 19 = 4 38596487E-07

LINER MODEL NASA V1B TEST K 30000 SIMP SUP ALUM EXIT END

COMPLIANCE MATRIX ASSEMBLY

COUPLING OF ELEMENT 19

ELEMNT 18 = 4 38596487E-07 ELEMNT 19 = 1 73001947E-06 ELEMNT 20 = 4 26413250E-07

COUPLING OF ELEMENT 20

ELEMNT 19 = 4 26413250E-07 ELEMNT 20 = 8 52826500E-07

COUPLING OF ELEMENT 23

ELEMNT 23 = 2 00374028E-07

COUPLING OF ELEMENT 24

ELEMNT 24 = 1 83214284E-06

COUPLING OF ELEMENT 25

ELEMNT 25 = 1 99361698E-06

COUPLING OF ELEMENT 26

ELEMNT 26 = 4 27659565E-07

COUPLING OF ELEMENT 27

ELEMNT 27 = 7 61016947E-07

COUPLING OF ELEMENT 28

ELEMNT 28 = 1 10169490E-06

COUPLING OF ELEMENT 29

ELEMNT 29 = 1 52542371E-06

COUPLING OF ELEMENT 30

ELEMNT 30 = 1 48305084E-06

COUPLING OF ELEMENT 31

ELEMNT 31 = 3 33333331E-05

COUPLING OF ELEMENT 32

ELEMNT 32 = 3 33333331E-05

COUPLING OF ELEMENT 33

ELEMNT 33 = 3 33333331E-05

COUPLING OF ELEMENT 34

ELEMNT 34 = 0 99999999E-05

COUPLING OF ELEMENT 35

ELEMNT 35 = 0 99999999E-06

COUPLING OF ELEMENT 38

ELEMNT 38 = 0 99999999E-01

LINER MODEL NASA V1B TEST K 30000 SIMP SUP ALUM EXIT END

INTERNAL LOAD INFLUENCE MATRIX
(RELATIVE TO A SUPPORTED STRUCTURE)

DEGREE OF FREEDOM 1

0	0	-1 00000000E 00	0	0	0	24
0	0	0	-1 00000000E 00	0	0	36

DEGREE OF FREEDOM 2

-7 13696760E 00	2 11591172E-01	2 11591172E-01	1 08005279E-01	1 08005279E-01	-8 11953676E-02	6
-6 63247573E-02	-6 63247573E-02	-3 31063339E-02	-3 46792468E-04	-1 70952430E-04	-3.63024756E-01	12
-2 11583501E-01	-1 07997622E-01	8 12029624E-02	6 63324082E-02	3 31139848E-02	3 54443121E-04	18
1 78603083E-04	7 65065211E-06	-9 79807818E-01	1 95376560E-05	0	0	24
-2 75904772E-02	2 35837939E-03	5 02038825E-03	-9 99999952E-01	0	-7 13696760E 00	36
-3 63024756E-01	7 65065211E-06					38

DEGREE OF FREEDOM 3

-1 05153662E 01	-3 76640084E 00	-3 76640084E 00	8 49891365E-01	8.49891365E-01	-8 84011590E-02	6
-9 05606019E-02	-9 05606019E-02	-9 53843379E-02	-1 71950097E-02	-8 47642553E-03	-2 11457184E 00	12
-1 36353731E 00	-8 49829519E-01	8 84630263E-02	9 06225014E-02	9 54462373E-02	1 72569090E-02	18
8 53832459E-03	6 18991178E-05	-8 99862051E-01	9 68733501E-04	0	0	24
-9 90636134E-02	-1 31034611E-02	1 06039111E-02	-9 99999917E-01	0	-1 05153662E 01	36
-2 11457184E 00	6 18991178E-05					38

LINER MODEL NASA VIB TEST K 30000 SIMP SUP. ALUM EXIT END

INTERNAL LOAD INFLUENCE MATRIX
(RELATIVE TO A SUPPORTED STRUCTURE)

DEGREE OF FREEDOM 4

-1 43323791E 01	-8 87613404E 00	-8 87613404E 00	-5.14406240E 00	-5 14406240E 00	1 67260660E 00	6
1 20463647E 00	1 20463647E 00	1 59270199E-01	-1 41002737E-01	-6 95083755E-02	-7 66730624E 00	12
-5 62355173E 00	-4 22562325E 00	-1 67229234E 00	-1 20432217E 00	-1 58955909E-01	1 41317028E-01	18
6 98226666E-02	3 14290860E-04	-7 27499348E-01	7 94381541E-03	0	0	24
-3 96796551E-02	-1 86625165E-01	-5 41396451E-02	-9 99999869E-01	0	-1 43323791E 01	36
-7 66730624E 00	3 14290860E-04					38

DEGREE OF FREEDOM 5

-1 53256598E 01	-9 91175318E 00	-9 91175318E 00	-6 20864099E 00	-6 20864099E 00	5 55133289E-01	6
1 88390274E 00	1 88390274E 00	3 62149119E-01	-1 82826322E-01	-9 01256359E-02	-8 68395305E 00	12
-6 59786028E 00	-5 17097259E 00	-2 56474677E 00	-1 88351619E 00	-3 61762574E-01	1 83212866E-01	18
9 05121779E-02	3 86542922E-04	-7 21854228E-01	1 03000727E-02	0	0	24
6 07748669E-02	-2 55078265E-01	-9 41424453E-02	-9 99999857E-01	0	-1 53256598E 01	36
-8 68395305E 00	3 86542922E-04					38

DEGREE OF FREEDOM 6

-1 78630234E 01	-1 22675692E 01	-1 22675692E 01	-8.44027865E 00	-8 44027865E 00	-1 44969109E 00	6
-6 15437001E-01	-6 15437001E-01	1 24814554E 00	-2 08142135E-01	-1 02605285E-01	-1 06364068E 01	12
-8 73186159E 00	-7 42915231E 00	-5 04974002E 00	-3 87399420E 00	-1 24757671E 00	2 08710942E-01	18
1 03174095E-01	5 68809438E-04	-7 46060562E-01	1 17263193E-02	0	0	24
3 31008780E-01	-3 60903963E-01	-2 35770571E-01	-9 99999821E-01	0	-1 78630234E 01	36
-1 06364068E 01	5 68809438E-04					38

DEGREE OF FREEDOM 7

-2 18902165E 01	-1 57572624E 01	-1 57572624E 01	-1 15623218E 01	-1 15623218E 01	-3 90021789E 00	6
-3 50234058E 00	-3 50234058E 00	-2 61355007E 00	3 91829088E-01	1 93155178E-01	-1 31088933E 01	12
-1 17418483E 01	-1 08067892E 01	-9 09889376E 00	-7 48677111E 00	-3 88556150E 00	-3 90940654E-01	18
-1 92266741E-01	8 88436985E-04	-8 17727208E-01	-2 20748764E-02	0	0	24
6 19778323E-01	-2 64417133E-01	-5 15559107E-01	-9 99999774E-01	0	-2 18902165E 01	36
-1 31088933E 01	8 88436985E-04					38

DEGREE OF FREEDOM 8

-2 75622022E 01	-2 06386429E 01	-2 06386429E 01	-1 59029284E 01	-1 59029284E 01	-7 25309503E 00	6
-7 12208128E 00	-7 12208128E 00	-6 82941878E 00	-5 18034154E 00	1 88293028E 00	-1 64363514E 01	12
-1 58599116E 01	-1 54656269E 01	-1 47454615E 01	-1 28664754E 01	-8 66913795E 00	-3 81821531E 00	18
-1 88148713E 00	1 44314353E-03	-9 23141241E-01	-2 15192032E-01	0	0	24
8 57960296E-01	-1 88523242E-01	-5 31103760E-01	-9 99999702E-01	0.	-2 75622022E 01	36
-1 64363514E 01	1 44314353E-03					38

DEGREE OF FREEDOM 9

-3 30727541E 01	-2 54016685E 01	-2 54016685E 01	-2 01546460E 01	-2 01546460E 01	-1 05709030E 01	6
-1 05333370E 01	-1 05333370E 01	-1 04494214E 01	-8 79734862E 00	-4 33672112E 00	-1 96751876E 01	12
-1 98462752E 01	-1 99632984E 01	-2 01770431E 01	-1 82046093E 01	-1 37985250E 01	-8 95059824E 00	18
-4 41122580E 00	2 05306453E-03	-1 02281143E 00	-5 04374725E-01	0	0	24
1 00412197E 00	-2 35475594E-01	-2 41460198E-01	-9 99999619E-01	0	-3 30727541E 01	36
-1 96751876E 01	2 05306453E-03					38

DEGREE OF FREEDOM 10

-2 31613731E 00	-1 34993155E 00	-1 34993155E 00	-6 89046830E-01	-6 89046830E-01	5 18066227E-01	6
4 23194069E-01	4 23194069E-01	2 11265692E-01	2 26217169E-03	1 11515822E-03	-5 18382931E 00	12
1 34996499E 00	6 89080268E-01	-5 18032807E-01	-4 23160648E-01	-2 11232275E-01	-2 22875410E-03	18
-1 08174060E-03	3 34176114E-05	-1 28827432E-01	-1 27446456E-04	0	0	24
1 76027516E-01	-1 50456975E-02	-3 20269400E-02	-1 00000000E 00	0	-2 31613731E 00	36
-5 18382931E 00	3 34176114E-05					38

DEGREE OF FREEDOM 11

-5 80817962E 00	-3 47412929E 00	-3 47412929E 00	-1 87763889E 00	-1 87763889E 00	1 03836800E 00	6
8 60666227E-01	8 60666227E-01	4 63710475E-01	1 59807682E-02	7.87785006E-03	-6 82172137E 00	12
-1 65577164E 00	1 87773797E 00	-1 03826898E 00	-8 60567200E-01	-4 63611442E-01	-1 58817396E-02	18
-7 77882117E-03	9 90288639E-05	-3 11206707E-01	-9 00325251E-04	0	0	24
3 99615562E-01	-1 95273645E-02	-6 79811645E-02	-9 99999988E-01	0	-5 80817962E 00	36
-6 82172137E 00	9 90288639E-05					38

DEGREE OF FREEDOM 12

-1 34107988E 01	-8 57877052E 00	-8 57877052E 00	-5 27366316E 00	-5 27366316E 00	7 63151020E-01	6
7 30185997E-01	7 30185997E-01	6 56547636E-01	1 01499960E-01	5 00351977E-02	-8 58887672E 00	12
-5 92090541E 00	-4 09601283E 00	-7 62826949E-01	-7 29861915E-01	-6 56223547E-01	-1 01175874E-01	18
-4 97111124E-02	3 24085516E-04	-6 44270450E-01	-5 71830744E-03	0	0	24
6 60670972E-01	6 89914179E-02	-7 96736383E-02	-9 99999940E-01	0	-1 34107988E 01	36
-8 58887672E 00	3 24085516E-04					38

DEGREE OF FREEDOM 13

-1 49079859E 01	-9 72011352E 00	-9 72011352E 00	-6 17160863E 00	-6 17160863E 00	3 09773582E-01	6
3 94683546E-01	3 94683546E-01	5 84357965E-01	1 31559590E-01	6 48533231E-02	-9 10162187E 00	12
-6 78949469E 00	-5 20799935E 00	-2 31938168E 00	-3 94291618E-01	-5 83966047E-01	-1 31167661E-01	18
-6.44613951E-02	3 91927683E-04	-6 91716343E-01	-7 41180736E-03	0	0	24
6 49472600E-01	1 11905029E-01	-6 22494793E-02	-9 99999928E-01	0	-1 49079859E 01	36
-9.10162187E 00	3 91927683E-04					38

DEGREE OF FREEDOM 14

-1 79723650E 01	-1 22318470E 01	-1 22318470E 01	-8 30533302E 00	-8 30533302E 00	-1 13351248E 00	6
-7 74170566E-01	-7 74170566E-01	2 85384321E-02	1 34687863E-01	6 63954240E-02	-1 09270666E 01	12
-8.76758504E 00	-7 56409949E 00	-5 36592013E 00	-3 71526200E 00	-2 79709902E-02	-1 34120421E-01	18
-6 58279824E-02	5 67441678E-04	-7 65402389E-01	-7 58804739E-03	0	0	24
5 86625338E-01	1 62446369E-01	2 39187300E-02	-9 99999893E-01	0	-1 79723650E 01	36
-1.05270666E 01	5 67441678E-04					38

LINER MODEL NASA VIB TEST K 30000 SIMP SUP ALUM EXIT END

INTERNAL LOAD INFLUENCE MATRIX
(RELATIVE TO A SUPPORTED STRUCTURE)

DEGREE OF FREEDOM 15

-2 20677808E 01	-1 57916284E 01	-1 57916284E 01	-1 14987400E 01	-1 14987400E 01	-3 65773353E 00	6
-3 17015558E 00	-3 17015558E 00	-2 08098900E 00	-4 73514616E-01	-2 33422700E-01	-1 29313451E 01	12
-1 17074986E 01	-1 08703873E 01	-9 34139431E 00	-7 81897229E 00	-4 41813880E 00	4 74386889E-01	18
2 34294575E-01	8 72274423E-04	-8 36820340E-01	2 66768813E-02	0	0	24
5 94244272E-01	-4 72768104E-03	2 20626867E-01	-9 99999833E-01	0	-2 20677808E 01	36
-1 25313451E 01	8 72274423E-04					38

DEGREE OF FREEDOM 16

-2 76459450E 01	-2 06727999E 01	-2 06727999E 01	-1 59031694E 01	-1 59031694E 01	-7 19138736E 00	6
-6 85056860E 00	-6 85096860E 00	-6 09053081E 00	-3 81541613E 00	-1 88083893E 00	-1 63526617E 01	12
-1 58258075E 01	-1 54654390E 01	-1 48072222E 01	-1 31376407E 01	-9 40807867E 00	-5 18319350E 00	18
1 88222927E 00	1 39033198E-03	-9 29752624E-01	2 14953020E-01	0	0	24
7 60390103E-01	-1 80655119E-01	1 35064632E-01	-9 99999714E-01	0	-2 76459450E 01	36
-1 63526617E 01	1 39033198E-03					38

DEGREE OF FREEDOM 17

0	0	0	0	-1 00000000E 00	0	36

DEGREE OF FREEDOM 18

0	0	0	0	1 00000000E 00	0	24
0	0	0	0	-1 00000000E 00	0	36

DEGREE OF FREEDOM 19

0	0	0	0	1 00000000E 00	1 00000000E 00	24
0	0	0	0	-1 00000000E 00	0	36

DEGREE OF FREEDOM 20

0	0	0	0	1 00000000E 00	1 00000000E 00	24
1 00000000E 00	0	0	0	0	0	30
0	0	0	0	-1 00000000E 00	0	36

DEGREE OF FREEDOM 21

0	0	0	0	1 00000000E 00	1 00000000E 00	24
1 00000000E 00	1 00000000E 00	0	0	0	0	30
0	0	0	0	-1 00000000E 00	0	36

DEGREE OF FREEDOM 22

0	0	0	0	1 00000000E 00	1 00000000E 00	24
1 00000000E 00	1 00000000E 00	1 00000000E 00	0	0	0	30
0	0	0	0	-1 00000000E 00	0	36

DEGREE OF FREEDOM 23

0	0	0	0	1 00000000E 00	1 00000000E 00	24
1 00000000E 00	1 00000000E 00	1 00000000E 00	1 00000000E 00	0	0	30
0	0	0	0	-1 00000000E 00	0	36

DEGREE OF FREEDOM 24

0	0	0	0	1 00000000E 00	1 00000000E 00	24
1 00000000E 00	1 00000000E 00	1 00000000E 00	1 00000000E 00	1 00000000E 00	0	30
0	0	0	0	-1 00000000E 00	0	36

DEGREE OF FREEDOM 25

0	0	0	0	1 00000000E 00	1 00000000E 00	24
1 00000000E 00	1 00000000E 00	1 00000000E 00	1 00000000E 00	1 00000000E 00	1 00000000E 00	30
0	0	0	0	-1 00000000E 00	0	36

LINER MODEL NASA VIB TEST K 30000 SIMP SUP ALUM EXIT END

DEFLECTION INFLUENCE MATRIX
(RELATIVE TO A SUPPORTED STRUCTURE)

DEGREE OF FREEDOM 1

0 99999999E-05	9 99999940E-06	9 99999917E-06	9 99999869E-06	9 99999857E-06	9 99999821E-06	6
9 99999774E-06	9 99999690E-06	9 99999619E-06	0 99999999E-05	9 99999976E-06	9 99999940E-06	12
9 99999928E-06	9 99999893E-06	9 99999833E-06	9 99999714E-06	0	0	18
0	0	0	0	0	0	24
0						25

LINER MODEL NASA VIB TEST K 30000 SIMP SUP ALUM EXIT END

DEFLECTION INFLUENCE MATRIX
(RELATIVE TO A SUPPORTED STRUCTURE)

DEGREE OF FREEDOM 2

9 99999940E-06	1 60419080E-05	2 06541267E-05	2 61295047E-05	2 74279907E-05	3 06205383E-05	6
3 55804718E-05	4 25517225E-05	4 93333995E-05	1 25702654E-05	1 64836553E-05	2 52098292E-05	12
2 65867468E-05	3 06991473E-05	3 57478184E-05	4 26383567E-05	0	0	18
0	0	0	0	0	0	24
0						25

DEGREE OF FREEDOM 3

9 99999917E-06	2 06541243E-05	5 20354760E-05	1 10967289E-04	1 22871317E-04	1 49899851E-04	6
1 89888543E-04	2 45817637E-04	3 00395009E-04	2 53308132E-05	4 94825560E-05	1 07665175E-04	12
1 20711115E-04	1 49463074E-04	1 90257216E-04	2 46200964E-04	0	0	18
0	0	0	0	0	0	24
0						25

DEGREE OF FREEDOM 4

9 99999869E-06	2 61294991E-05	1 10967287E-04	4 12460148E-04	4 78120536E-04	6 19829696E-04	6
8 22346234E-04	1 10455872E-03	1 38058728E-03	6 74511063E-05	1 62055953E-04	4 11137515E-04	12
4 72412819E-04	6 13608867E-04	8 20541584E-04	1 10531992E-03	0	0	18
0	0	0	0	0	0	24
0						25

DEGREE OF FREEDOM 5

9 99999857E-06	2 74279878E-05	1 22871320E-04	4 78120542E-04	5 59665334E-04	7 35125494E-04	6
9 84120381E-04	1 33076195E-03	1 66992088E-03	7 56956291E-05	1 85211112E-04	4 80146390E-04	12
5 54249012E-04	7 26622885E-04	9 80982292E-04	1 33135523E-03	0	0	18
0	0	0	0	0	0	24
0						25

DEGREE OF FREEDOM 6

9 99999821E-06	3.06205339E-05	1 49899855E-04	6 19829702E-04	7 35125488E-04	9 94198048E-04	6
1 36157390E-03	1 86991230E-03	2 36657363E-03	9 22496557E-05	2 33121276E-04	6 30863351E-04	12
7 35024095E-04	9 82167923E-04	1 35371488E-03	1 86847617E-03	0	0	18
0	0	0	0	0	0	24
0						25

DEGREE OF FREEDOM

9 99999774E-06	3 55804700E-05	1 89888550E-04	8 22346246E-04	9 84120381E-04	1 36157390E-03	6
1 93123999E-03	2 72142223E-03	3 48505512E-03	1 14056015E-04	2 97818983E-04	8 43005526E-04	12
9 91633856E-04	1 35276000E-03	1 91405469E-03	2 70838353E-03	0	0	18
0	0	0	0	0	0	24
0						25

DEGREE OF FREEDOM 8

9 99999690E-06	4 25517291E-05	2 45817658E-04	1 10455875E-03	1 33076197E-03	1 86991239E-03	6
2 72142228E-03	3 98611432E-03	5 20671827E-03	1 43587206E-04	3 85769022E-04	1 13315746E-03	12
1 34308472E-03	1 86362819E-03	2 70371881E-03	3 95097709E-03	0	0	18
0	0	0	0	0	0	24
0						25

DEGREE OF FREEDOM 9

9 99999619E-06	4 93333805E-05	3 00395000E-04	1 38058725E-03	1 66992085E-03	2 36657360E-03	6
3.48505512E-03	5 20671821E-03	6 98383218E-03	1 72271514E-04	4 71088368E-04	1 41405801E-03	12
1 68322857E-03	2 35872439E-03	3 47700644E-03	5 20384419E-03	0	0	18
0	0	0	0	0	0	24
0						25

DEGREE OF FREEDOM 10

0 99999999E-05	1 25702645E-05	2 53308132E-05	6 74511051E-05	7 56956273E-05	9 22496545E-05	6
1 14056015E-04	1 43587200E-04	1 72271518E-04	3 47195545E-05	5 19386351E-05	7 33186913E-05	12
7 85107940E-05	9 17481303E-05	1 12988451E-04	1 43034896E-04	0	0	18
0	0	0	0	0	0	24
0						25

DEGREE OF FREEDOM 11

9 99999976E-06	1 64836536E-05	4 94825572E-05	1 62055950E-04	1 85211109E-04	2 33121276E-04	6
2 97818586E-04	3 85769013E-04	4 71088380E-04	5 19386351E-05	1 01463388E-04	1 75376475E-04	12
1 91992636E-04	2 32470360E-04	2 95552948E-04	3 84466410E-04	0	0	18
0	0	0	0	0	0	24
0						25

DEGREE OF FREEDOM 12

9 99999940E-06	2 52098247E-05	1 07665175E-04	4 11137509E-04	4 80146384E-04	6 30863345E-04	6
8 43005526E-04	1 13315743E-03	1 41405803E-03	7 33186907E-05	1 75376473E-04	4 33159888E-04	12
4 94061905E-04	6 33163053E-04	8 40349734E-04	1 13066627E-03	0	0	18
0	0	0	0	0	0	24
0						25

DEGREE OF FREEDOM 13

9 99999928E-06	2 69867459E-05	1.20711119E-04	4.72412819E-04	5 54249012E-04	7 35024095E-04	6
9 91633856E-04	1 34308471E-03	1 68322861E-03	7 85107946E-05	1 91992638E-04	4 94061917E-04	12
5 68888640E-04	7 38754261E-04	9 89558887E-04	1 34052949E-03	0	0	18
0	0	0	0	0	0	24
0.						25

LINER MODEL NASA VIB TEST K 30000 SIMP SUP ALUM EXIT END

DEFLECTION INFLUENCE MATRIX
(RELATIVE TO A SUPPORTED STRUCTURE)

DEGREE OF FREEDOM 14

9 99999893E-06	3 06991395E-05	1 49463071E-04	6 13608861E-04	7 26622868E-04	9 82167912E-04	6
1 35275999E-03	1 86362815E-03	2 35872442E-03	9 17481291E-05	2 32470357E-04	6 33163047E-04	12
7 38754249E-04	9 87582779E-04	1 35355727E-03	1 86245432E-03	0	0	18
0	0	0	0	0	0	24
0						25

DEGREE OF FREEDOM 15

9 99999833E-06	3 57478186E-05	1 90257229E-04	8 20541584E-04	9 80982304E-04	1 35371490E-03	6
1 91405472E-03	2 70371881E-03	3 47700650E-03	1 12988453E-04	2 95552954E-04	8 40349746E-04	12
9 89558887E-04	1 35355730E-03	1 92140894E-03	2 71288568E-03	0	0	18
0	0	0	0	0	0	24
0						25

DEGREE OF FREEDOM 16

9 99999714E-06	4 26383507E-05	2 46200970E-04	1 10531992E-03	1 33135523E-03	1 86847617E-03	6
2 70838353E-03	3 95097694E-03	5 20384425E-03	1 43034895E-04	3 84466404E-04	1 13066627E-03	12
1 34052547E-03	1 86245434E-03	2 71288565E-03	3 98027062E-03	0	0	18
0	0	0	0	0	0	24
0						25

DEGREE OF FREEDOM 17

0	0	0	0	0	0	6
0	0	0	0	0	0	12
0	0	0	0	0 99999999E-06	0 99999999E-06	18
0 99999999E-06	0 99999999E-06	0 99999999E-06	0 99999999E-06	0 99999999E-06	0 99999999E-06	24
0 99999999E-06						25

DEGREE OF FREEDOM 18

0	0	0	0	0	0	6
0	0	0	0	0	0	12
0	0	0	0	0 99999999E-06	1 20037402E-06	18
1 20037402E-06	1 20037402E-06	1 20037402E-06	1 20037402E-06	1 20037402E-06	1 20037402E-06	24
1 20037402E-06						25

DEGREE OF FREEDOM 19

0	0	0	0	0	0	6
0	0	0	0	0	0	12
0	0	0	0	0 99999999E-06	1.20037402E-06	18
3 03251687E-06	3 03251687E-06	3 03251687E-06	3 03251687E-06	3 03251687E-06	3 03251687E-06	24
3 03251687E-06						25

DEGREE OF FREEDOM 20

0	0	0	0	0	0	6
0	0	0	0	0	0	12
0	0	0	0	0 99999999E-06	1 20037402E-06	18
3 03251687E-06	5 02613384E-06	5 02613384E-06	5 02613384E-06	5 02613384E-06	5 02613384E-06	24
5 02613384E-06						25

DEGREE OF FREEDOM 21

0	0	0	0	0	0	6
0	0	0	0	0	0	12
0	0	0	0	0 99999999E-06	1 20037402E-06	18
3 03251687E-06	5 02613384E-06	5 45379341E-06	5 45379341E-06	5 45379341E-06	5 45379341E-06	24
5 45379341E-06						25

DEGREE OF FREEDOM 22

0	0	0	0	0	0	6
0	0	0	0	0	0	12
0	0	0	0	0 99999999E-06	1 20037402E-06	18
3 03251687E-06	5 02613384E-06	5 45379341E-06	6 21481037E-06	6 21481037E-06	6 21481037E-06	24
6 21481037E-06						25

DEGREE OF FREEDOM 23

0	0	0	0	0	0	6
0	0	0	0	0	0	12
0	0	0	0	0 99999999E-06	1 20037402E-06	18
3 03251687E-06	5 02613384E-06	5 45379341E-06	6 21481037E-06	7 31650525E-06	7 31650525E-06	24
7 31650525E-06						25

DEGREE OF FREEDOM 24

0	0	0	0	0	0.	6
0	0	0	0	0	0.	12
0	0	0	0	0 99999999E-06	1 20037402E-06	18
3 03251687E-06	5 02613384E-06	5 45379341E-06	6 21481037E-06	7 31650525E-06	8 84192896E-06	24
8 84192896E-06						25

DEGREE OF FREEDOM 25

0	0	0	0	0	0	6
0.	0	0	0.	0	0.	12
0	0	0	0	0 99999999E-06	1 20037402E-06	18
3 03251687E-06	5 02613384E-06	5 45379341E-06	6 21481037E-06	7 31650525E-06	8 84192896E-06	24
1 03249797E-05						25

LINER MODEL NASA VIB TEST K 30000 SIMP SUP ALUM EXIT END

ORDINARY MASS MATRIX

GRID POINT 1, UNIT LOADS 1 - 1, (1,0,0,0,0,0)

2.59067357E+00	0	0	0	0	0
0	2.59067357E+00	0	0	0	0
0	0	2.59067357E+00	0	0	0
0	0	0	-0	0	0
0	0	0	0	-0	0
0	0	0	0	0	-0

GRID POINT 2, UNIT LOADS 2 - 2, (1,0,0,0,0,0)

6.06217605E-03	0	0	0	0	0
0	6.06217605E-03	0	0	0	0
0	0	6.06217605E-03	0	0	0
0	0	0	-0	0	0
0	0	0	0	-0	0
0	0	0	0	0	-0

GRID POINT 3, UNIT LOADS 3 - 3, (1,0,0,0,0,0)

1.08031087E-02	0	0	0	0	0
0	1.08031087E-02	0	0	0	0
0	0	1.08031087E-02	0	0	0
0	0	0	-0	0	0
0	0	0	0	-0	0
0	0	0	0	0	-0

GRID POINT 4, UNIT LOADS 4 - 4, (1,0,0,0,0,0)

8.67875636E-03	0	0	0	0	0
0	8.67875636E-03	0	0	0	0
0	0	8.67875636E-03	0	0	0
0	0	0	-0	0	0
0	0	0	0	-0	0
0	0	0	0	0	-0

GRID POINT 5, UNIT LOADS 5 - 5, (1.0,0,0,0,0)

5.15544033E-03	0	0	0	0	0
0	5.15544033E-03	0	0	0	0
0	0	5.15544033E-03	0	0	0
0	0	0	-0	0	0
0	0	0	0	-0	0
0	0	0	0	0	-0

GRID POINT 6, UNIT LOADS 6 - 6, (1.0 0,0,0,0)

8.34196881E-03	0	0	0	0	0
0	8.34196881E-03	0	0	0	0
0	0	8.34196881E-03	0	0	0
0	0	0	-0	0	0
0	0	0	0	-0	0
0	0	0	0	0	-0

GRID POINT 7, UNIT LOADS 7 - 7, (1,0 0 0,0,0)

1.24352328E-02	0	0	0	0	0
0.	1.24352328E-02	0	0	0	0
0	0	1.24352328E-02	0	0	0
0	0	0	-0	0	0
0	0	0	0	-0	0
0	0	0	0	0	-0

GRID POINT 8, UNIT LOADS 8 - 8, (1,0,0,0,0,0)

1.43264246E-02	0	0	0	0	0
0	1.43264246E-02	0	0	0	0
0	0	1.43264246E-02	0	0	0
0	0	0	-0	0	0
0	0	0	0	-0	0
0	0	0	0	0	-0

GRID POINT 9, UNIT LOADS 9 - 9, (1,0,0,0,0,0)

2.59067357E+00	0	0	0	0	0
0	2.59067357E+00	0	0	0	0
0	0	2.59067357E+00	0	0	0
0	0	0	-0	0	0
0	0	0	0	-0	0
0	0	0	0	0	-0

GRID POINT 11, UNIT LOADS 10 - 10, (1,0,0,0,0,0)

7.25388587E-04	0	0	0	0	0
0	7.25388587E-04	0	0	0	0
0	0	7.25388587E-04	0	0	0
0	0	0	-0	0	0
0	0	0	0	-0	0
0	0	0	0	0	-0

GRID POINT 12, UNIT LOADS 11 - 11, (1,0,0,0,0,0)

8.54922259E-04	0	0	0	0	0
0	8.54922259E-04	0	0	0	0
0	0	8.54922259E-04	0	0	0
0	0	0	-0	0	0
0	0	0	0	-0	0
0	0	0	0	0	-0

LINER MODEL NASA VIB TEST K 30000 SIMP SUP ALUM EXIT END

ORDINARY MASS MATRIX

GRID POINT 13, UNIT LOADS 12 - 12, (1,0,0,0,0,0)

6.73575121E-04	0	0	0	0	0
0	6.73575121E-04	0	0	0	0
0	0	6.73575121E-04	0	0	0
0	0	0	-0	0	0
0	0	0	0	-0	0
0	0	0	0	0	-0

GRID POINT 14, UNIT LOADS 13 - 13, (1 0,0,0,0,0)

3.88601029E-04	0	0	0	0	0
0	3.88601029E-04	0	0	0	0
0	0	3.88601029E-04	0	0	0
0	0	0	-0	0	0
0	0	0	0	-0	0
0	0	0	0	0	-0

GRID POINT 15, UNIT LOADS 14 - 14, (1,0,0,0,0,0)

6.47668391E-04	0	0	0	0	0
0	6.47668391E-04	0	0	0	0
0	0	6.47668391E-04	0	0	0
0	0	0	-0	0	0
0	0	0	0	-0	0
0	0	0	0	0	-0

GRID POINT 16 UNIT LOADS 15 - 15, (1 0,0,0,0,0)

9.32642484E-04	0	0	0	0	0
0	9.32642484E-04	0	0	0	0
0	0	9.32642484E-04	0	0	0
0	0	0	-0	0	0
0	0	0	0	-0	0
0	0	0	0	0	-0

GRID POINT 17, UNIT LOADS 16 - 16, (1,0,0,0,0,0)

1.01036267E-03	0	0	0	0	0
0	1.01036267E-03	0	0	0	0
0	0	1.01036267E-03	0	0	0
0	0	0	-0	0	0
0	0	0	0	-0	0
0	0	0	0	0	-0

GRID POINT 1 UNIT LOADS 17 - 17, (1,0,0,0,0,0)

5.18134713E 00	0	0	0	0	0
0	5.18134713E 00	0	0	0	0
0	0	5.18134713E 00	0	0	0
0	0	0	-0	0	0
0	0	0	0	-0	0
0	0	0	0	0	-0

GRID POINT 2 UNIT LOADS 18 - 18, (1,0,0,0,0,0)

6.62176C5E-03	0	0	0	0	0
0	6.62176C5E-03	0	0	0	0
0	0	6.62176C5E-03	0	0	0
0	0	0	-0	0	0
0	0	0	0	-0	0
0	0	0	0	0	-0

GRID POINT 3, UNIT LOADS 19 - 19, (1,0,0,0,0,0)

1.08031087E-02	0	0	0	0	0
0	1.08031087E-02	0	0	0	0
0	0	1.08031087E-02	0	0	0
0	0	0	-0	0	0
0	0	0	0	-0	0
0	0	0	0	0	-0

GRID POINT 4, UNIT LOADS 20 - 20, (1,0,0,0,0,0)

8.67875636E-03	0	0	0	0	0
0	8.67875636E-03	0	0	0	0
0	0	8.67875636E-03	0	0	0
0	0	0	-0	0	0
0	0	0	0	-0	0
0	0	0	0	0	-0

GRID POINT 5, UNIT LOADS 21 - 21, (1,0,0,0,0,0)

5.15544033E-03	0	0	0	0	0
0	5.15544033E-03	0	0	0	0
0	0	5.15544033E-03	0	0	0
0	0	0	-0	0	0
0	0	0	0	-0	0
0	0	0	0	0	-0

LINER MODEL NASA VIB TEST K 30000 SIMP SUP ALUM EXIT END

ORDINARY MASS MATRIX

GRID POINT 6, UNIT LOADS 22 - 22, (1,0 0,0,0 0)

8 83419681E-03	0	0	0	0
0	8 83419681E-03	0	0	0
0	0	8 83419681E-03	0	0
0	0	0	-0	0
0	0	0	0	-0
0	0	0	0	0

GRID POINT 7 UNIT LOADS 23 - 23 (1,0,0,0,0 0)

1 24352328E-02	0	0	0	0
0	1 24352328E-02	0	0	0
0	0	1 24352328E-02	0	0
0	0	0	-0	0
0	0	0	0	-0
0	0	0	0	0

GRID POINT 8, UNIT LOADS 24 - 24, (1 0,0 0,0 0)

1 43264246E-02	0	0	0	0
0	1 43264246E-02	0	0	0
0	0	1 43264246E-02	0	0
0	0	0	-0	0
0	0	0	0	-0
0	0	0	0	0

GRID POINT 9, UNIT LOADS 25 - 25, (1 0 0 0,0,0)

2 15025,02E-03	0	0	0	0
0	2 15025902E-03	0	0	0
0	0	2 15025902E-03	0	0
0	0	0	-0	0
0	0	0	0	-0
0	0	0	0	0

LINER MODEL NASA VIB TEST K 30000 SIMP SUP ALUM EXIT END

OVERALL MASS MATRIX

5 24979270E 00	0
0	5 252875636 00

DETERMINANT = 2 75765079E 01

INVERSE

1 904837C9E-01	0
0	1 90371915E-01

INVERSION CHECK

1 00000000E 00	0
0	1 00000000E 00

LINER MODEL NASA VIB TEST K 30000 SIMP SUP ALUM EXIT END

INPUT DATA

```
   35   37    1    1
   38   33   16    2          1         1
1 1 1
  1

END
```

LINER MODEL NASA VIB TEST K 30000 SIMP SUP ALUM EXIT END

INVERSION CHECK FOR THE A MATRIX

```
 9 99999988E-01   9 99999988E-01   9 99999988E-01   9 99999988E-01   9 99999988E-01   9 99999988E-01   6
 9 99999988E-01   1 00000000E 00   9 99999988E-01   1 00000000E 00   9 99999988E-01   1 00000000E 00  12
 9 99999988E-01   9 99999988E-01   1 00000000E 00   1 00000000E 00                                    16
                          DETERMINANT =  0
```

LINER MODEL NASA VIB TEST K 30000 SIMP SUP ALUM EXIT END

INITIAL STIFFNESS MATRIX
(RELATIVE TO A SUPPORTED STRUCTURE)

DEGREE OF FREEDOM 1

```
 3 58257279E 05  -2 41628879E 05   5 56759387E 04  -2 07935205E 04   1 40685338E 04  -1 31777588E 03   6
 2 03021672E 02  -3 50171882E 01   1 01141578E 01  -1 11530680E 05   5 33022308E 04  -1 61619076E 04  12
 1 07335675E 04  -8 97384620E 02   1 38416271E 02  -2 39337093E 01                                   16
```

DEGREE OF FREEDOM 2

```
-2 41628879E 05   3 67198342E 05  -1 57648638E 05   8 47694428E 04  -5 73534822E 04   5 37215680E 03   6
-8 27879775E 02   1 43067110E 02  -2 45972127E 01   4 15256196E-02  -1 12976748E-01   8 95442665E-01  12
-1 31878C71E 00   6 40375495E-01  -1 91774200E-01   2 27494431E-02                                   16
```

DEGREE OF FREEDOM 3

```
 5 56759387E 04  -1 57648638E 05   1 47036029E 05  -1 50466776E 05   1 14730662E 05  -1 07464148E 04   6
 1 65627038E 03  -2 86431056E 02   4 92979872E 01   3 04742262E-02  -1 28799725E-02   6 92516327E-02  12
-1 23727266E-01   1 74509977E-01  -1 44886407E-01   6 72181219E-02                                   16
```

DEGREE OF FREEDOM 4

```
-2 07935205E 04   8 47694428E 04  -1 50466776E 05   8 39262927E 05  -9 58030808E 05   2 71052852E 05   6
-4 17750669E 04   7 22482312E 03  -1 24402268E 03  -1 82969627E-01   7 11587131E-02  -3 00008708E 04  12
 1 50594647E 00  -1 50801304E 00   9 56427616E-01  -3 27368850E-01                                   16
```

DEGREE OF FREEDOM 5

```
 1 40685338E 04  -5 73534822E 04   1 14730662E 05  -9 58030808E 05   1 27758422E 06  -4 83689827E 05   6
 1 08177742E 05  -1 87091181E 04   3 22168538E 03   2 00412199E-01  -3 26413426E-02   7 48968750E-01  12
-1 37730593E 00   1 54568417E 00  -9 75009978E-01   2 64013621E-01                                   16
```

DEGREE OF FREEDOM 6

```
-1 31777588E 03   5 37215680E 03  -1 07464148E 04   2 71052852E 05  -4 83689827E 05   3 60303319E 05   6
-1 41534428E 05   3 69173783E 04  -6 35731232E 03   2 32574403E-02  -1 98562780E-01   1 16289042E 00  12
-1 43784338E 00  -2 99996310E 04   2 96827057E-02   1 01765475E-01                                   16
```

DEGREE OF FREEDOM 7

```
 2 03021672E 02  -8 27879775E 02   1 65627038E 03  -4 17750669E 04   1 08177742E 05  -1 41534428E 05   6
 1 46248470E 05  -5 65521836E 04   1 44043253E 04  -7 63081944E-02   2 00220689E-01  -1 28138691E 00  12
 1 63058618E 00  -6 74660522E-01  -2 99998948E 04  -1 74089763E-01                                   16
```

DEGREE OF FREEDOM 8

```
-3 50171882E 01   1 43067110E 02  -2 86431056E 02   1 22482312E 03  -1 87091181E 04   3 69173783E 04   6
-5 65521836E 04   4 92417341E 04  -1 79444775E 04   4 95360923E-02  -1 28805387E-01   1 01481591E 00  12
-1 34162490E 00   6 80082953E-01  -1 61281672E-01   1 12327836E-01                                   16
```

LINER MODEL NASA VIB TEST K 30000 SIMP SUP ALUM EXIT END

INITIAL STIFFNESS MATRIX
(RELATIVE TO A SUPPORTED STRUCTURE)

DEGREE OF FREEDOM 9

1 01141578E 01	-2 45972127E 01	4 92979872E 01	-1 24402268E 03	3 22168538E 03	-6 35731232E 03	6
1 44043253E 04	-1 79444775E 04	1 60855764E 04	-2 49334460E 01	5 73243982E 01	-1 40472518E 03	12
3.50668192E 03	-6 66445082E 03	1 49734816E 04	-1 86439683E 04			16

DEGREE OF FREEDOM 10

-1 11530690E 05	4 15256172E-02	3 04742280E-02	-1 82969633E-01	2 00412202E-01	2 32314388E-02	6
-7 63081926E-02	4 95360911E-02	-2 49334460E 01	2 44998333E 05	-1 71091078E 05	9 79579914E 04	12
-6.50522071E 04	5 43532079E 03	-8 37628782E 02	1 44806893E 02			16

DEGREE OF FREEDOM 11

5 33022308E 04	-1 12976743E-01	-1 28799759E-02	7 11587209E-02	-3 26413479E-02	-1 98562782E-01	6
2.00220689E-01	-1 28805386E-01	5 73243982E 01	-1 71091078E 05	1 79319397E 05	-2 00204223E 05	12
1 49516845E 05	-1 24927169E 04	1 92530121E 03	-3 32863912E 02			16

DEGREE OF FREEDOM 12

-1 61619076E 04	8 95442629E-01	6 92516506E-02	-3 00008708E 04	7 48968738E-01	1 16289045E 00	6
-1 28138693E 00	1 01481591E 00	-1 40472518E 03	9 79579914E 04	-2 00204223E 05	1 01860985E 06	12
-1 13582766E 06	3 06039232E 05	-4 71670717E 04	8 15678322E 03			16

DEGREE OF FREEDOM 13

1 07335675E 04	-1 31878068E 00	-1 23727287E-01	1 50594649E 00	-1 37730995E 00	-1 43784343E 00	6
1 63058619E 00	-1 34162492E 00	3 50668192E 03	-6 50522071E 04	1 49516845E 05	-1 13582766E 06	12
1 47702645E 06	-5 37283480E 05	1 17745209E 05	-2 03629333E 04			16

DEGREE OF FREEDOM 14

-8 97384620E 02	6 40375483E-01	1 74509987E-01	-1 50801307E 00	1 54568420E 00	-2 99996310E 04	6
-6 74660534E-01	6 80082959E-01	-6 66445082E 03	5 43532079E 03	-1 24927169E 04	3 06039232E 05	12
-5 37283480E 05	3 86212978E 05	-1 49051337E 05	3 87006092E 04			16

DEGREE OF FREEDOM 15

1 38416271E 02	-1 91774200E-01	-1 44886412E-01	9 56427634E-01	-9 75010014E-01	2 96827078E-02	6
-2 95998948E 04	-1 61281677E-01	1 49734816E 04	-8 37628782E 02	1 92530121E 03	-4 71670717E 04	12
1 17745209E 05	-1 49051337E 05	1 51078235E 05	-5 88042289E 04			16

DEGREE OF FREEDOM 16

-2 35337093E 01	2 27494431E-02	6 72181237E-02	-3 27368864E-01	2 64013642E-01	1 01765469E-01	6
-1 74089763E-01	1 12322836E-01	-1 86439683E 04	1 44806893E 02	-3 32863912E 02	8 15678322E 03	12
-2 03629333E 04	3 87006092E 04	-5 88042289E 04	5 11656624E 04			16

LINER MODEL NASA VIB TEST K 30000 SIMP SUP ALUM EXIT END

DIFFERENTIAL STIFFNESS MATRIX
(UNCOUPLED TERMS)

0	0	0	0	0	0	6
0	0	0	0	0	0	12
0	0	0	0			16

THE DIFFERENTIAL STIFFNESS MATRIX IS A DIAGONAL MATRIX

LINER MODEL NASA VIB TEST K 30000 SIMP SUP ALUM EXIT END

REVISED STIFFNESS MATRIX
(RELATIVE TO A SUPPORTED STRUCTURE)

DEGREE OF FREEDOM 1

3 58257279E C5	-2 41628879E 05	5 56759387E 04	-2 07935205E 04	1 40685338E 04	-1 31777588E 03	6
2 03021672E 02	-3 5C171882E 01	1 01141578E 01	-1 11530690E 05	5 33022308E 04	-1 61619076E 04	12
1 07335675E C4	-8 97384620E 02	1 38416271E 02	-2 39337093E 01			16

DEGREE OF FREEDOM 2

-2 41628675E 05	3 67198342E 05	-1 57648638E 05	8 47699428E 04	-5 73534822E 04	5 37215680E 03	6
-8 27879775E 02	1 43067110E 02	-2 45972127E 01	0	0	0	12
0	0	0	0			16

DEGREE OF FREEDOM 3

5 56759387E C4	-1 57648638E 05	1 47036029E 05	-1 50466776E 05	1 14730662E 05	-1 07464148E 04	6
1 65627038E C3	-2 86431056E 02	4 92979872E 01	0	0	0	12
0	0	0	0			16

DEGREE OF FREEDOM 4

-2 07935205E 04	8 47699428E 04	-1 50466776E 05	8 39262927E 05	-9 58030808E 05	2 71052852E 05	6
-4 17750669E C4	7 22482312E 03	-1 24402268E 03	0	0	-3 00008708E 04	12
0	0	0	0			16

DEGREE OF FREEDOM 5

1 40685338E C4	-5 73534822E 04	1 14730662E 05	-9 58030808E 05	1 27758422E 06	-4 83689827E 05	6
1 08177742E C5	-1 87091181E 04	3 22168538E 03	0	0	0	12
0	0	0	0			16

DEGREE OF FREEDOM 6

-1 31777588E 03	5 37215680E 03	-1 07464148E 04	2 71052852E 05	-4 83689827E 05	3 60303319E 05	6
-1 41534428E C5	3 69173783E 04	-6 35731232E 03	0	0	0	12
0	-2 99998310E 04	0	0			16

DEGREE OF FREEDOM 7

2 03021672E 02	-8 27879775E 02	1 65627038E 03	-4 17750669E 04	1 08177742E 05	-1 41534428E 05	6
1 46248470E C5	-5 65521836E 04	1 44043253E 04	0	0	0	12
0	0	-2 99998948E 04	0			16

DEGREE OF FREEDOM 8

-3 5C171882E 01	1 43067110E 02	-2 86431056E 02	7 22482312E 03	-1 87091181E 04	3 69173783E 04	6
-5 65521836E C4	4 92417341E 04	-1 79444775E 04	0	0	0	12
0	0	0	0			16

DEGREE OF FREEDOM 9

1 01141578E C1	-2 45972127E 01	4 92979872E 01	-1 24402268E 03	3 22168538E 03	-6 35731232E 03	6
1 44043253E C4	-1 79444775E 04	1 60855764E 04	-2 49334460E 01	5 73243982E 01	-1 40472518E 03	12
3 50668192E C3	-6 6C445082E C3	1 49734816E 04	-1 86439683E 04			16

DEGREE OF FREEDOM 10

-1 11530690E 05	0	0	0	0	0	6
0	0	-2 49334460E 01	2 44998333E 05	-1 71091078E 05	9 79579914E 04	12
-6 50522071E 04	5 43532079E 03	-8 37628782E 02	1 44806893E 02			16

DEGREE OF FREEDOM 11

5 33022308E C4	0	0	0	0	0	6
0	0	5 73243982E 01	-1 71091078E 05	1 79319497E 05	-2 00204223E 05	12
1 49516845E C5	-1 24927169E 04	1 92530121E 03	-3 32863912E 02			16

DEGREE OF FREEDOM 12

-1 61619076E 04	0	0	-3 00008708E 04	0	0	6
0	0	-1 40472518E 03	9 79579914E 04	-2 00204223E 05	1 01860985E 06	12
-1 13582766E 06	3 06039232E 05	-4 71670717E 04	8 15678322E 03			16

DEGREE OF FREEDOM 13

1 07335675E C4	0	0	0	0	0	6
0	0	3 50668192E 03	-6 50522071E 04	1 49516845E 05	-1 13582766E 06	12
1 47702645E 06	-5 37283480E 05	1 17745209E 05	-2 03629333E 04			16

DEGREE OF FREEDOM 14

-8 97384620E 02	0	0	0	0	-2 99998310E 04	6
0	0	-6 66445082E 03	5 43532079E 03	-1 24927169E 04	3 06039232E 05	12
-5 37283480E 05	3 86217978E 05	-1 49051337E 05	3 87006092E 04			16

DEGREE OF FREEDOM 15

1 38416271E 02	0	0	0	0	0	6
-2 99998948E 04	0	1 49734816E 04	-8 37628782E 02	1 92530121E 03	-4 71670717E 04	12
1 17745209E 05	-1 49051337E C5	1 51078235E 05	-5 88042289E 04			16

DEGREE OF FREEDOM 16

-2 39337093E C1	0	0	0	0	0	6
0	0	-1 86439683E 04	1 44806893E 02	-3 32863912E 02	8 15678322E 03	12
-2 03629333E 04	3 87006092E 04	-5 88042289E 04	5 11656624E 04			16

LINER MODEL NASA V1B TEST K 30000 SIMP SUP ALUM EXIT END

INVERSION CHECK FOR THE AI+DS MATRIX

1 0F0073000E 00	9 99999952E-01	9 999999952E-01	1 0000000 61E 00	9 999968889E-01	1 000000212E 00	6
1 000002216E 00	9 99999464E-01	9 99999774E-01	1 0000000 12E 00	9 99999917E-01	9 99998879E-01	12
9 9599980216-01	9 99995053E-01	1 C00C0034E 00	9 C 999201E-01			16

DETERMINANT = 1 701411816 38

LINER MODEL NASA V1B TEST K 30000 SIMP SUP ALUM EXIT END

REVISED DEFLECTION INFLUENCE MATRIX
(RELATIVE TO A SUPPORTED STRUCTURE)

DEGREE OF FREEDOM 1

1 0L0C3912E-05	1 30C71964E-05	1 000C6919E-05	1 00022063E-05	1 00024725E-05	1 00029723E-05	6
1 0003683 0E-05	1 03C48430E-05	1 0005973 1E-05	1 00004745E-05	1 000010476E-05	1 00022639E-05	12
1 0L02481 E-05	1 00C29784E-05	1 00036722E-05	1 00047889E-05			16

DEGREE OF FREEDOM 2

1 0C 0L 1564E-05	1 6 422956E-05	2 06553495E-05	2 61328998E-05	2 74316573E-05	3 06245631E-05	6
3 5585J229E-05	4 25576353E-05	4 934C6230E-05	1 25711466E-05	1 64854959E-05	2 52133366E-05	12
2 6994 4321E-05	3 07C32073E-05	3 5752370 7E-05	4 26441032E-05			16

DEGREE OF FREEDOM 3

1 0000 6919E-05	2 06553495E-05	5 20385319E-05	1 10972865E-04	1 22876407E-04	1 49902810E-04	6
1 89888 58E-04	2 45E16928E-04	3 1 0393674E-04	2 53332439E-05	4 94870585E-05	1 07671048E-04	12
1 20716229E-04	1 49466255E-04	1 90257348E-04	2 46199533E-04			16

DEGREE OF FREEDOM 4

1 00022063E-05	2 61328998E-05	1 10972865E-04	4 12456715E-04	4 78110790E-04	6 19801855E-04	6
8 22293127E-04	1 10448518E-03	1 38049443E-03	6 74565607E-05	1 62063599E-04	4 11134559E-04	12
4 72402841E-04	6 13582063E-04	8 20489168E-04	1 10524350E-03			16

DEGREE OF FREEDOM 5

1 00024725E-05	2 74316573E-05	1 22876407E-04	4 78110790E-04	5 59647179E-04	7 35083944E-04	6
9 84046149E-04	1 33065996E-03	1 66979261E-03	7 57019961E-05	1 85217801E-04	4 99137933E-04	12
5 54230511E-04	7 26582587E-04	9 80908942E-04	1 33124986E-03			16

DEGREE OF FREEDOM 6

1 00029723E-05	3 06245631E-05	1 49902810E-04	6 19801855E-04	7 35083944E-04	9 94110835E-04	6
1 36144446E- 3	1 86973621E-03	2 36635336E-03	9 22544730E-05	2 33124200E-04	6 30835629E-04	12
7 34981877E-04	9 82091475E-04	1 35358676E-03	1 86829559E-03			16

DEGREE OF FREEDOM 7

1 00036830E-05	3 55850229E-05	1 89888558E-04	8 22293127E-04	9 84046149E-04	1 36144446E-03	6
1 93103355E-03	2 72114384E-03	3 48470867E-03	1 14059958E-04	2 97816721E-04	8 42952263E-04	12
9 91558952E-04	1 35263321E-03	1 91385031E-03	2 70809895E-03			16

DEGREE OF FREEDOM 8

1 00048430E-05	4 25575353E-05	2 45816928E-04	1 10448518E-03	1 33065996E-03	1 86973621E-03	6
2 72114384E-03	3 98574430E-03	5 20626241E-03	1 43591921E-04	3 85764790E-04	1 13308378E-03	12
1 34298125E-03	1 86345565E-03	2 70344344E-03	3 95059851E-03			16

DEGREE OF FREEDOM 9

1 00059731E-05	4 93406230E-05	3 00393674E-04	1 38049443E-03	1 66979261E-03	2 36635336E-03	6
3 48470867E-03	5 20626241E-03	6 98327470E-03	1 72277062E-04	4 71082449E-04	1 41398526E-03	12
1 68309858E-03	2 35850927E-03	3 47666416E-03	5 20337784E-03			16

DEGREE OF FREEDOM 10

1 00004745E-05	1 25711466E-05	2 53332439E-05	6 74565607E-05	7 57019961E-05	9 22544730E-05	6
1 14059958E-04	1 43591921E-04	1 72277062E-04	3 47213790E-05	5 19421935E-05	7 33242947E-05	12
7 85162252E-05	9 17530417E-05	1 12992446E-04	1 43039183E-04			16

DEGREE OF FREEDOM 11

1 00010476E-05	1 64854959E-05	4 94870585E-05	1 62063599E-04	1 85217801E-04	2 33124200E-04	6
2 97816721E-04	3 85764790E-04	4 71082449E-04	5 19421935E-05	1 01469868E-04	1 75344377E-04	12
1 91999207E-04	2 32473567E-04	2 95550874E-04	3 84461102E-04			16

LINER MODEL NASA V1B TEST K 30000 SIMP SUP ALUM EXIT END

REVISED DEFLECTION INFLUENCE MATRIX
(RELATIVE TO A SUPPORTED STRUCTURE)

DEGREE OF FREEDOM 12

1 000226 39E-05	2 52133366E-05	1 07671048E-04	4 11134559E-04	4 80137038F-04	6 30835629E-04	6
8.42952263E-04	1 13308378E-03	1 41396526E-03	7 33242947E-05	1 75386377E-04	4 33157223E-04	12
4 94052166E-04	6 33136344E-04	8 40297222E-04	1 13058974E-03			16

DEGREE OF FREEDOM 13

1 00024810E-05	2 69904321E-05	1 20716229E-04	4 72402841E-04	5 54230511E-04	7 34981877E-04	6
9 91558352E-04	1 34298125E-03	1 68309858E-03	7 85162252E-05	1 91999207E-04	4 94052166E-04	12
5 [illegible]	7 38713276E-04	9 89484489E-04	1 34042266E-03			16

DEGREE OF FREEDOM 14

1 00029794E-05	3 07C32073E-05	1 49466255E-04	6 13582063E-04	7 26582587E-04	9 82091475E-04	6
1 35263321E-03	1 86345595E-03	2 35850927E-03	9 17530417E-05	2 32473567E-04	6 33136344E-04	12
7 38713276E-04	9 87578166E-04	1 353431 88E-03	1 86227764E-03			16

DEGREE OF FREEDOM 15

1 00036722E-05	3 57523707E-05	1 90257348E-04	8 20489168E-04	9 80908942E-04	1 35359676E-03	6
1 91385031E-03	2 70344344E-03	3 47666416E-03	1 12992446E-04	2 95550874E-04	8 40297222E-04	12
9 89484 19E-04	1 35343188E-03	1 92120662E-03	2 71260419E-03			16

DEGREE OF FREEDOM 16

1 00047889E-05	4 26441032E-05	2 46199533E-04	1 10524350E-03	1 33124986E-04	1 86829558E-03	6
2 70809956E-03	3 95059851E-03	5 20337784E-03	1 43039183E-04	3 84461102E-04	1 13058974E-03	12
1 34042266E- 3	1 86227764E-03	2 71260419E-03	3 97988379E-03			16

USE ENTRY POINT 38 FOR THE NEXT RUN

FINAL TIME 00 374 DATE 12/28/65

LINER MODEL NASA V1B TEST K 30000 SIMP SUP ALUM EXIT END

I N P U T D A T A

```
 35  87   1   1
 38  33  25   2          1       1                          PRINT 4
          1   1          1 1   1                            STIFF
 23                                                         MODES
     1                                                      DAMPING
   1 0            1 0                                       RENORM
1 1 1 1                                                     PRINT 5
  2                                                         LOS
 17 2026 42                                                  21
  1 1015 815      9 1015 815                                 21
1 0                                                         X
             1 0                                            Y
END
          1   1                                             PRINT 6
                                                            STRESS
  1  6579        2  6579        3  05234        4  05234
  5  05234       6  05234       7  05234        8  05234
  9  05234      10  05234      11  05234       12  2736
 13  2736       14  2736       15  2736        16  2736
 17  2736       18  2736       19  2736        20  2736
 23  1 337      24  1          25  1           26  1
 27  1          28  1          29  1           30  1
 31  30000 0    32  30000 0    33  30000 0
END
```

LINER MODEL NASA VIB TEST K 30000 SIMP SUP ALUM EXIT END

EIGENVALUES OF THE L MATRIX

9 07855535E-03	7 07220018E-06	7 51876771E-07	2 35238358E-07	1 22318394E-07	4 73618221E-08	6
4 25963497E-08	3 09848154E-08	1 89201565E-08	1 47896688E-08	8 16763544E-09	2 80597320E-09	12
2 56088287E-09	1 69055371E-09	1 18747833E-11	1 82737221E-10	2 81578106E-07	2 74303973E-08	18
1 10288C15E-08	6 78104311E-09	3 27373877E-09	2 70594671E-09	8 13698089E-14	1 09661592E-09	24
1 04496945E-09						25

LINER MODEL NASA VIB TEST K 30000 SIMP SUP ALUM EXIT END

UNDAMPED FREQUENCIES
(RADIANS/SECOND)

1 0495221BE 01	3 76030195E 02	1 15325850E 03	1 88451916E 03	2 06179711E 03	2 85926303E 03	6
4 59500295E 03	4 84522343E 03	5 68100983E 03	6 03787261E 03	7 27005398E 03	8 22281981E 03	12
9 52216752E 03	1 16650103E 04	1 21437198E 04	1 74774468E 04	1 88780978E 04	1 92238504E 04	18
1 97608280E 04	2 43212286E 04	3 03362548E 04	3 09348631E 04	7 39752579E 04	0	24
0						25

LINER MODEL NASA VIB TEST K 30000 SIMP SUP ALUM EXIT END

UNDAMPED FREQUENCIES
(CYCLES/SECOND)

1 67036644E 00	5 98470640E 01	1 83546789E 02	2 99930537E 02	3 28145200E 02	4 55065840E 02	6
7 31317437E 02	7 71141255E 02	9 04160786E 02	9 60957265E 02	1 15706502E 03	1 30870241E 03	12
1 51550018E 03	1 76105109E 03	1 93273303E 03	2 78162202E 03	3 00454256E 03	3 05957079E 03	18
3 14503345E 03	3 87084377E 03	4 82816494E 03	4 92343634E 03	1 17735279E 04	0	24
0						25

$\omega = 598$ cps

LINER MODEL NASA VIB TEST K 30000 SIMP SUP ALUM EXIT END

DAMPED FREQUENCIES
(RADIANS/SECOND)

1 04431359E 01	3 74164030E 02	1 14753509E 03	1 87516667E 03	2 05156481E 03	2 84507304E 03	6
4 57219887E 03	4 82117754E 03	5 65281612E 03	6 00790781E 03	7 23397410E 03	8 18201160E 03	12
9 47491121E 03	1 10100968E 04	1 20834528E 04	1 73907094E 04	1 87844093E 04	1 91284460E 04	18
1 96627590E 04	2 42005274E 04	3 01857018E 04	3 07813394E 04	7 36081326E 04	0	24
0						25

LINER MODEL NASA VIB TEST K 30000 SIMP SUP ALUM EXIT END

DAMPED FREQUENCIES
(CYCLES/SECOND)

1 66207673E 00	5 95500547E 01	1 82635881E 02	2 98442042E 02	3 26516682E 02	4 52807432E 02	6
7 27688338E 02	7 67314231E 02	8 99673617E 02	9 56188214E 02	1 15132274E 03	1 30220757E 03	12
1 50797996E 03	1 75231133E 03	1 92314126E 03	2 76781735E 03	2 98963159E 03	3 04438671E 03	18
3 12942529E 03	3 85163355E 03	4 80420363E 03	4 89900225E 03	1 17150980E 04	0	24
0						25

LINER MODEL NASA VIB TEST K 30000 SIMP SUP ALUM EXIT END

NORMALIZED MODE SHAPES
(RELATIVE TO A FREE-FREE STRUCTURE)

MODE 1

4 36430198E-01	4 31496328E-01	3 99969003E-01	2 64255583E-01	2 27895889E-01	1 40340525E-01	6
-2 45682922E-04	-2 16656241E-01	-4 40020025E-01	4 16053003E-01	3 74520182E-01	2 60043532E-01	12
2 26218024E-01	1 41324003E-01	7 69014966E-04	-2 16283911E-01	0	0	18
0	0	0	0	0	0	24
0						25

MODE 2

-5 38431227E-02	1 61896887E-01	1 12396628E 00	3 91251150E 00	4 35795587E 00	4 99487144E 00	6
5 00055236E 00	3 20379159E 00	-3 82639071E-02	6 85153824E-01	1 76226039E 00	3 92207581E 00	12
4 29336894E 00	4 85529953E 00	4 78518760E 00	2 91424805E 00	0	0	18
0	0	0	0	0	0	24
0						25

MODE 3

2 60483608E-02	-7 31798249E-01	-2 82098139E 00	-4 91232806E 00	-4 41945928E 00	-2 12692043E 00	6
2 47688317E 00	5 64209569E 00	-2 09970349E-02	-1 23482627E 00	-2 68556356E 00	-3 64511108E 00	12
-3 22298688E 00	-1 69956000E 00	8 66562748E-01	1 58829270E 00	0	0	18
0	0	0	0	0	0	24
0						25

MODE 4

0	0	0	0	0	0	6
0	0	0	0	0	0	12
0	0	0	0	-4 60480809E-02	1 23735924E-01	18
1 67129464E 00	3 22741249E 00	3 51868087E 00	3 98796302E 00	4 52948290E 00	4 97414333E 00	24
5 03112215E 00						25

MODE 5

-2 89353824E-02	2 61740574E 00	6 64800048E 00	1 93171741E 00	3 00306812E-02	-3 25628406E 00	6
-2 75446913E 00	4 07866031E 00	-7 46176457E-03	5 32464015E-01	9 89299177E-01	1 75791320E-01	12
-4 35759003E-01	-1 95672889E 00	-3 19088057E 00	-2 60352498E 00	0	0	18
0	0	0	0	0	0	24
0						25

MODE 6

1 66670674E-02	-2 96524084E 00	-5 25585783E 00	3 91993365E 00	3 81850207E 00	-1 10640962E-02	6
-4 41494232E 00	3 05366969E 00	-3 59262931E-03	1 88142385E 00	3 56905642E 00	3 20375010E 00	12
2 33944878E 00	-3 16544056E-01	-4 16474503E 00	-4 90145826E 00	0	0	18
0	0	0	0	0	0	24
0						25

MODE 7

-5 42820770E-03	4 30410999E-01	2 85898155E-01	-1 41775465E 00	-1 01308012E 00	8 89090763E-01	6
2 73234603E 00	-3 34932759E-01	5 11535925E-03	6 80053693E 00	1 11982709E 01	5 97936098E 00	12
3 74377680E 00	-2 29565606E 00	-1 38904652E 01	-2 33871019E 01	0	0	18
0	0	0	0	0	0	24
0						25

MODE 8

7 02966535E-03	1 89557087E-01	1 57292493E-01	7 31796223E-01	1 58374909E 00	2 36926180E 00	6
1 09319173E-01	1 98187710E-01	1 54359327E-03	-1 37440090E 01	-2 22288162E 01	-1 40293437E 01	12
-1 13636542E 01	-7 14150691E 00	-7 48602400E 00	-1 02174587E 01	0	0	18
0	0	0	0	0	0	24
0						25

LINER MODEL NASA VIB TEST K 30000 SIMP SUP ALUM EXIT END

NORMALIZED MODE SHAPES
(RELATIVE TO A FREE-FREE STRUCTURE)

MODE 9

6 82261880E-03	-2 73208377E 00	-8 03401172E-01	4 94364840E 00	5 57122338E-01	-7 42941344E 00	6
4 04220265E 00	-1 15648317E 00	1 47370629E-03	-1 15989818E 00	-1 87554799E 00	-2 37651145E 00	12
-2 88850358E 00	-3 63277686E 00	-1 98319896E 00	-8 56201589E-01	0	0	18
0	0	0	0	0	0	24
0						25

MODE 10

0	0	0	0	0	0	6
0	0	0	0	0	0	12
0	0	0	0	1 16279109E-02	-4 28474456E-01	18
-4 27910829E 00	-5 10932767E 00	-4 59608865E 00	-3 02540380E 00	3 21860588E-01	4 73395747E 00	24
5 35670-96E 00						25

MODE 11

-4 77932[illegible]	4 19126207E-01	-2 50174338E-02	3 29054335E-01	1 05940256E 00	1 55761023E 00	6
3 35011941E-[illegible]	3 04567025E-02	-1 80902500E-03	1 08784902E 01	1 13535668E 01	-1 46391501E 01	12
-1 89536[illegible]	-2 11267846E 01	-9 81119945E 00	1 04286447E 01	0	0	18
0		0	0	0	0	24
0						25

MODE 12

1 71753E73E-02	-1 18342651E 01	3 17006260E 00	-1 03527303E 00	-1 36084597E 00	1 49098162E 00	6
-4 35529537E-01	1 03249715E-01	-1 65562628E-04	4 75677764E-01	4 29957610E-01	-5 02048749E-01	12
-5 04019320E-01	-2 66405[illegible]5E-01	-1 10414182E-01	1 32905704E-01	0	0	18
0	0	0	0	0	0	24
0						25

MODE 13

0	0	0	0	0	0	6
0	0	0	0	0	0	12
0	0	0	0	-8 37894797E-03	7 80381864E-01	18
7 20660746E 00	1 25997539E-01	-1 43529782E 00	-3 70301926E 00	-3 71810710E 00	2 65596354E 00	24
3 73630476E 00						25

MODE 14

-2 40104851E-03	2 02547961E-02	-6 98732460E-03	3 61650988E-01	4 13077885E-01	-2 62844318E-01	6
-4 21596736E-01	5 28661066E-03	1 58906256E-03	1 01767518E 01	4 62718987E 00	-1 75763430E 01	12
-1 40934148E 01	4 92643223E 00	2 15571501E 01	-1 28678199E 01	0	0	18
0	0	0	0	0	0	24
0						25

MODE 15

0	0	0	0	0	0	6
0	0	0	0	0	0	12
0	0	0	0	3 20102811E-03	-4 86889452E-01	18
-4 17060393E 00	5 06726974E 00	4 27539510E 00	3 92600039E-01	-5 79185688E 00	1 84694090E 00	24
3 48659152E 00						25

MODE 16

0	0	0	0	0	0	6
0	0	0	0	0	0	12
0	0	0	0	-5 20457679E-04	1 64533019E-01	18
1 11552268E 00	-6 16628636E 00	-6 58544886E-01	8 19129682E 00	-3 34865570E 00	7 55550867E-02	24
2 91430432E 00						25

MODE 17

6 33553607E-04	-6 81840158E-01	6 10328925E-01	-5 30248463E 00	1 15598127E 01	-2 54952380E 00	6
4 29419178E-01	-7 37459183E-02	1 48346353E-04	-3 15410706E-01	1 49513777E-01	5 52074897E-01	12
5 20783107E-01	7 00469854E-01	-4 22156131E-02	1 31536424E-02	0	0	18
0	0	0	0	0	0	24
0						25

MODE 18

0	0	0	0	0	0	6
0	0	0	0	0	0	12
0	0	0	0	2 92130750E-05	-1 11766768E-02	18
-6 77633011E-02	4 10003483E-01	-4 98791760E-02	-7 95914876E-01	9 86765087E-01	-3 46221864E 00	24
1 93572159E 01						25

MODE 19

2 98706937E-03	-4 89791298E-04	-1 10244513E-04	-6 39016068E-02	-6 85858321E-02	2 12424386E-01	6
-8 22025526E-02	2 39660722E-03	3 55130899E-04	-2 32180899E 01	1 14179733E 01	9 65381122E 00	12
-3 75372130E 00	-2 09565359E 01	1 17402029E 01	-3 94149753E 00	0	0	18
0	0	0	0	0	0	24
0						25

MODE 20

1 97013645E-03	2 63164224E-03	-2 62986779E-03	9 95998025E-02	-1 80434054E-02	-1 24649429E-01	6
3 59634418E-02	-7 30057607E-04	-2 70153874E-04	-1 93063329E 01	1 54259877E 01	-1 48471120E 01	12
-6 41339111E 00	2 12262556E 01	-8 27459252E 00	2 39636534E 00	0	0	18
0	0	0	0	0	0	24
0						25

LINER MODEL NASA VIB TEST K 30000 SIMP SUP ALUM EXIT END

NORMALIZED MODE SHAPES
(RELATIVE TO A FREE-FREE STRUCTURE)

MODE 21

0	0	0	0	0	0	6
0	0	0	0	0	0	12
0	0	0	0	1 33982396E-02	-1 27782032E 01	18
7 72401784E-01	2 19454502E-01	-6 48400545E-01	1 46437374E-01	-1 35155274E-02	7 70769322E-04	24
-3 98947453E-04						25

MODE 22

0	0	0	0	0	0	6
0	0	0	0	0	0	12
0	0	0	0	6 46296275E-04	-6 41986883E-01	18
3 11C514C1E-01	-5 16796254E 00	1 17931564E 01	-2 51601386E 00	2 71493906E-01	-1 20373721E-02	24
5 86C4F18CE-03						25

MODE 23

-4 81161577E-04	-5 22644102E-04	-5 88429207E-04	1 18517929E-02	-1 09722173E-03	5 21898115E-03	6
-1 22136111E-03	-5 50644215E-04	-5 36511111E-04	-1 36256595E 00	2 33729175E 00	-1 92294031E 01	12
4 21166666E 01	-9 11233099E 00	1 46224056E 00	-2 65992945E-01	0	0	18
0	0	0	0	0	0	24
0						25

LINER MODEL NASA VIB TEST K 30000 SIMP SUP ALUM EXIT END

MODAL MASSES

5 16481C3CE 0C	2 99911627E-02	3 14136997E-02	3 95066556E-02	2 26265272E-02	3 62003499E-02	6
1 82829876E-03	2 02 79670E-03	1 81171940E-02	3 48501280E-02	2 23831981E-03	7 14031541E-03	12
1 92547666E-02	2 15187439E-03	2 98101628E-02	1 49037193E-02	7 48339009E-03	2 65778056E-03	18
1 85501324E-03	2 21949062E-03	6 12435567E-03	7 19018173E-03	5 63935554E-04		23

LINER MODEL NASA VIB TEST K 30000 SIMP SUP ALUM EXIT END

RENORMALIZED MODE SHAPES
(RELATIVE TO A FREE-FREE STRUCTURE)

MODE SHAPE 1

-9 91841674E-01	0	0	0	0	0	1
-9 80628846E-01	0	0	0	0	0	2
-9 08979082E-01	0	0	0	0	0	3
-6 00553 30E-01	0	0	0	0	0	4
-5 17921633E-01	0	0	0	0	0	5
-3 18941224E-01	0	0	0	0	0	6
5 58344865E-04	0	0	0	0	0	7
4 92378134E-01	0	0	0	0	0	8
1 000 60006 (0	0	0	0	0	0	9
-9 45531964E-01	0	0	0	0	0	11
-8 60233586E-01	0	0	0	0	0	12
-5 90981126E-01	0	0	0	0	0	13
-5 14108467E-01	0	0	0	0	0	14
-3 21176796E-01	0	0	0	0	0	15
-1 74768175E-03	0	0	0	0	0	16
4 91531568E-01	0	0	0	0	0	17

LINER MODEL NASA V18 TEST K-30000 SIMP SUP ALUM EXIT END

RENORMALIZED MODE SHAPES
(RELATIVE TO A FREE-FREE STRUCTURE)

MODE SHAPE 2

-1 0767435CE-02	0	0	0	0	0	1
3 23758CC6E-02	0	0	0	0	0	2
2 24768424E-01	0	0	0	0	0	3
7 82415855E-01	0	0	0	0	0	4
6 71494889E-01	0	0	0	0	0	5
9 98863935E-01	0	0	0	0	0	6
1 0C00C J00E 00	0	0	0	0	0	7
6 4C687531E-01	0	0	0	0	0	8
-7 6513360E-03	0	0	0	0	0	9
1 37015627E-01	0	0	0	0	0	11
3 52413142E-01	0	0	0	0	0	12
7 84328508E-01	0	0	0	0	0	13
8 58578532E-01	0	0	0	0	0	14
9 70852630E-01	0	0	0	0	0	15
9 5C931794E-01	0	0	0	0	0	16
5 82785225E-01	0	0	0	0	0	17

MODE SHAPE 3

4 61678815E-03	0	0	0	0	0	1
-1 29703266E-01	0	0	0	0	0	2
-4 9998821EE-01	0	0	0	0	0	3
-8 70656621E-01	0	0	0	0	0	4
-7 83301J06E-01	0	0	0	0	0	5
-3 76973474E-01	0	0	0	0	0	6
4 39000053E-01	0	0	0	0	0	7
1 0C00030CE 00	0	0	0	0	0	8
-3 72145 72E-03	0	0	0	0	0	9
-2 18859494E-01	0	0	0	0	0	11
-4 75986980E-01	0	0	0	0	0	12
-6 46056223E-01	0	0	0	0	0	13
-5 76434505E-01	0	0	0	0	0	14
-3 01228493E-01	0	0	0	0	0	15
1 53588306E-01	0	0	0	0	0	16
2 81507576E-01	0	0	0	0	0	17

MODE SHAPE 4

-9 15264618E-03	0	0	0	0	0	1
2 45941004E-02	0	0	0	0	0	2
3 32191223E-01	0	0	0	0	0	3
6 41489583E-01	0	0	0	0	0	4
6 99382907E-01	0	0	0	0	0	5
7 92658752E-01	0	0	0	0	0	6
9 00292767E-01	0	0	0	0	0	7
9 88674712E-01	0	0	0	0	0	8
1 0C0L0000E 00	0	0	0	0	0	9

MODE SHAPE 5

-4 3 245 00E-03	0	0	0	0	0	1
3 92713227E-01	0	0	0	0	0	2
1 CC0L0L0CE 00	0	0	0	0	0	3
2 90571186E-01	0	0	0	0	0	4
4 51725C07E-03	0	0	0	0	0	5
-4 85814C49E-01	0	0	0	0	0	6
-4 14330455E-01	0	0	0	0	0	7
6 13510843E-01	0	0	0	0	0	8
-1 12240734E-03	0	0	0	0	0	9
8 01938 94E-02	0	0	0	0	0	11
1 48811387E-01	0	0	0	0	0	12
2 64427358E-02	0	0	0	0	0	13
-6 55533548E-03	0	0	0	0	0	14
-2 94634286E-01	0	0	0	0	0	15
-4 79975975E-01	0	0	0	0	0	16
-3 91625264E-01	0	0	0	0	0	17

MODE SHAPE 6

-3 17114121E-03	0	0	0	0	0	1
5 64178276E-01	0	0	0	0	0	2
1 0CC0000CE 00	0	0	0	0	0	3
-7 45821851E-01	0	0	0	0	0	4
-7 26523C83E-01	0	0	0	0	0	5
2 1050 9110E-03	0	0	0	0	0	6
8 40004122E-01	0	0	0	0	0	7
-5 81013100E-01	0	0	0	0	0	8
6 83547658E-04	0	0	0	0	0	9
-3 57967034E-01	0	0	0	0	0	11
-6 79062581E-01	0	0	0	0	0	12
-6 05557374E-01	0	0	0	0	0	13
-4 45112640E-01	0	0	0	0	0	14
6 02269059E-02	0	0	0	0	0	15
7 92700616E-01	0	0	0	0	0	16
9 32570853E-01	0	0	0	0	0	17

LINER MODEL NASA VIB TEST K 30000 SIMP SUP ALUM EXIT END

RENORMALIZED MODE SHAPES
(RELATIVE TO A FREE-FREE STRUCTURE)

MODE SHAPE 7

2 32102621E-04	0	0	0	0	0	1
-1 84037764E-02	0	0	0	0	0	2
-1 22246079E-02	0	0	0	0	0	3
6 06212187E-02	0	0	0	0	0	4
4 33178985E-02	0	0	0	0	0	5
-3 80158582E-02	0	0	0	0	0	6
-9 54520142E-02	0	0	0	0	0	7
1 43212 94E-02	0	0	0	0	0	8
-2 18725654E-04	0	0	0	0	0	9
-2 90781507E-01	0	0	0	0	0	11
-4 74974191E-01	0	0	0	0	0	12
-2 55669150E-01	0	0	0	0	0	13
-1 60078694E-01	0	0	0	0	0	14
9 81590629E-02	0	0	0	0	0	15
5 93936992E-01	0	0	0	0	0	16
1 00000000E 00	0	0	0	0	0	17

MODE SHAPE 8

-3 16241100E-04	0	0	0	0	0	1
-8 52753842E-03	0	0	0	0	0	2
-7 07606238E-03	0	0	0	0	0	3
-3 29210612E-02	0	0	0	0	0	4
-7 12479463E-02	0	0	0	0	0	5
-1 06585152E-01	0	0	0	0	0	6
-4 91790342E-03	0	0	0	0	0	7
-8 91580129E-03	0	0	0	0	0	8
-6 94410514E-05	0	0	0	0	0	9
6 18296933E-01	0	0	0	0	0	11
1 00000000E 00	0	0	0	0	0	12
6 31133187E-01	0	0	0	0	0	13
5 11214542E-01	0	0	0	0	0	14
3 21272478E-01	0	0	0	0	0	15
3 32272479E-01	0	0	0	0	0	16
4 59424311E-01	0	0	0	0	0	17

MODE SHAPE 9

-9 18244600E-04	0	0	0	0	0	1
3 67738822E-01	0	0	0	0	0	2
1 08137900E-01	0	0	0	0	0	3
-6 65415704E-01	0	0	0	0	0	4
-7 49887377E-02	0	0	0	0	0	5
1 00000000E 00	0	0	0	0	0	6
-5 44680985E-01	0	0	0	0	0	7
1 55662782E-01	0	0	0	0	0	8
-1 98361056E-04	0	0	0	0	0	9
1 56122442E-01	0	0	0	0	0	11
2 52448957E-01	0	0	0	0	0	12
3 19878745E-01	0	0	0	0	0	13
3 88792950E-01	0	0	0	0	0	14
4 88972223E-01	0	0	0	0	0	15
2 66938829E-01	0	0	0	0	0	16
1 15244843E-01	0	0	0	0	0	17

MODE SHAPE 10

2 17072037E-03	0	0	0	0	0	1
-7 99884218E-02	0	0	0	0	0	2
-7 98832017E-01	0	0	0	0	0	3
-9 53818941E-01	0	0	0	0	0	4
-8 58006513E-01	0	0	0	0	0	5
-5 64788091E-01	0	0	0	0	0	6
6 00855434E-02	0	0	0	0	0	7
8 83744121E-01	0	0	0	0	0	8
1 00000000E 00	0	0	0	0	0	9

MODE SHAPE 11

2 26117483E-04	0	0	0	0	0	1
-1 98292316E-02	0	0	0	0	0	2
1 18359694E-03	0	0	0	0	0	3
-1 55678518E-02	0	0	0	0	0	4
-5 01212722E-02	0	0	0	0	0	5
-7 41650271E-02	0	0	0	0	0	6
-1 58492182E-02	0	0	0	0	0	7
-1 44282600E-03	0	0	0	0	0	8
8 55865729E-05	0	0	0	0	0	9
-5 14671004E-01	0	0	0	0	0	11
-5 37147295E-01	0	0	0	0	0	12
6 92591143E-01	0	0	0	0	0	13
8 96729362E-01	0	0	0	0	0	14
1 00000000E 00	0	0	0	0	0	15
4 64176536E-01	0	0	0	0	0	16
-4 93388420E-01	0	0	0	0	0	17

LINER MODEL NASA VIB TEST K 30000 SIMP SUP ALUM EXIT END

RENORMALIZED MODE SHAPES
(RELATIVE TO A FREE-FREE STRUCTURE)

MODE SHAPE 12

-1 45115618E-03	0	0	0	0	0	1
1 0000000E 00	0	0	0	0	0	2
-2 67871517E-01	0	0	0	0	0	3
8 74809706E-02	0	0	0	0	0	4
1 14992011E-01	0	0	0	0	0	5
-1 25584524E-01	0	0	0	0	0	6
3 68020761E-02	0	0	0	0	0	7
-8 73305100E-03	0	0	0	0	0	8
1 3590 1761E-05	0	0	0	0	0	9
-4 01949549E-02	0	0	0	0	0	11
-3 63315845E-02	0	0	0	0	0	12
4 24233139E-02	0	0	0	0	0	13
4 25898278E-02	0	0	0	0	0	14
2 25113514E-02	0	0	0	0	0	15
9 33004105E-03	0	0	0	0	0	16
-1 12305835E-02	0	0	0	0	0	17

MODE SHAPE 13

-1 1e2c7573E-03	0	0	0	0	0	1
1 08266953E-01	0	0	0	0	0	2
1 0000000E 00	0	0	0	0	0	3
1 74836133E-02	0	0	0	0	0	4
-1 99164145E-01	0	0	0	0	0	5
- 13836670E-01	0	0	0	0	0	6
-5 15930283E-01	0	0	0	0	0	7
3 68545607E-01	0	0	0	0	0	8
5 18455422E-01	0	0	0	0	0	9

MODE SHAPE 14

-1 11380561E-04	0	0	0	0	0	1
9 39585578E-04	0	0	0	0	0	2
-3 24130115E-04	0	0	0	0	0	3
1 67763747E-02	0	0	0	0	0	4
1 91619817E-02	0	0	0	0	0	5
-1 21929012E-02	0	0	0	0	0	6
-1 95571 61E-02	0	0	0	0	0	7
2 45236886E-04	0	0	0	0	0	8
7 37139124E-05	0	0	0	0	0	9
4 72082227E-01	0	0	0	0	0	11
2 14647475E-01	0	0	0	0	0	12
-8 15336880E-01	0	0	0	0	0	13
-6 53769 71E-01	0	0	0	0	0	14
2 28621550E-01	0	0	0	0	0	15
1 0000000E 00	0	0	0	0	0	16
-5 96916294E-01	0	0	0	0	0	17

MODE SHAPE 15

-5 52677345E-04	0	0	0	0	0	1
8 46444825E-02	0	0	0	0	0	2
7 20080120E-01	0	0	0	0	0	3
-8 74893525E-01	0	0	0	0	0	4
-7 38173467E-01	0	0	0	0	0	5
-6 77846804E-02	0	0	0	0	0	6
1 0000000E 00	0	0	0	0	0	7
-3 18885794E-01	0	0	0	0	0	8
-6 01961640E-01	0	0	0	0	0	9

MODE SHAPE 16

-6 35378F55E-05	0	0	0	0	0	1
2 00863209E-02	0	0	0	0	0	2
1 36183891E-01	0	0	0	0	0	3
-6 33901105E-01	0	0	0	0	0	4
-8 03956807E-02	0	0	0	0	0	5
1 0000000E 00	0	0	0	0	0	6
-4 68806533E-01	0	0	0	0	0	7
9 22382474E-03	0	0	0	0	0	8
3 55786575E-01	0	0	0	0	0	9

MODE SHAPE 17

5 46411649E-05	0	0	0	0	0	1
-5.89836069E-02	0	0	0	0	0	2
5 27974743E-02	0	0	0	0	0	3
-4 5E65985E-01	0	0	0	0	0	4
1 0000000E 00	0	0	0	0	0	5
-2 20550609E-01	0	0	0	0	0	6
3 71475884E-02	0	0	0	0	0	7
-6 37950790E-03	0	0	0	0	0	8
1 28329371E-05	0	0	0	0	0	9
-2 72851047E-02	0	0	0	0	0	11
1 29335269E-02	0	0	0	0	0	12
4 77581173E-02	0	0	0	0	0	13
4 50511616E-02	0	0	0	0	0	14
1 73419634E-02	0	0	0	0	0	15
-3 65152876E-03	0	0	0	0	0	16
1 12787675E-03	0	0	0	0	0	17

LINER MODEL NASA VIB TEST K 30000 SIMP SUP ALUM EXIT END

RENORMALIZED MODE SHAPES
(RELATIVE TO A FREE-FREE STRUCTURE)

MODE SHAPE 18

1 50604115E- 6	C	0	0	0	0	1
-5 76198673E-04	0	0	0	0	0	2
-3 49344671E-03	C	0	0	0	0	3
2 11371830E-02	0	0	0	0	0	4
-2 57145444E-03	0	0	0	0	0	5
-4 10323310E-02	0	0	0	0	0	6
5 08713585E-02	0	0	0	0	0	7
-1 78490167E-01	0	0	0	0	0	8
1 CCOLC000E 00	0	0	0	0	0	9

MODE SHAPE 19

-1 28652674E-04	0	0	0	0	0	1
2 10952449E-05	)	0	0	0	0	2
4 74821621E-06	C	0	0	0	0	3
2 75223354E-03	C	C	0	0	0	4
2 95358253E-03	0	0	0	0	0	5
-9 14908546E-03	C	0	0	0	0	6
3 54045281E-03	0	0	0	0	0	7
-1 03230162E-04	0	0	0	0	0	8
-1 52954358E-05	C	0	0	0	0	9
1 0001000CE 00	0	C	0	0	0	11
-4 91770371E-01	0	0	0	0	0	12
-4 15788.41E-01	0	0	0	0	0	13
1 61672267E-01	0	0	0	0	0	14
9 02505162E-01	0	C	0	0	0	15
-5 05678953E-01	0	0	0	0	0	16
1 65759765E-01	0	0	0	0	0	17

MODE SHAPE 20

9 28160119E-05	C	0	0	0	0	1
1 23933406E-04	0	C	0	0	0	2
-1 23896922E-04	0	0	0	0	0	3
4 69229251E-03	0	0	0	0	0	4
-8 50051248E-04	0	0	0	0	0	5
-5 87241715E-03	0	0	0	0	0	6
1 69451396E-03	0	0	0	0	0	7
-3 44C 505CE-05	0	0	0	0	0	8
-1 27273446E-05	0	0	0	0	0	9
-9 05549218E-01	0	0	0	0	0	11
7 26740873E-01	0	0	0	0	0	12
-6 99469185E-01	0	0	0	0	0	13
-3 02142313E-01	0	0	0	0	0	14
1 0000C00E 00	0	0	0	0	0	15
-3 85828166E-01	C	0	0	0	0	16
1 12856280E-01	C	0	0	0	0	17

MODE SHAPE 21

-1 04852795E-03	0	0	0	0	0	1
1 0000C00E 00	0	0	0	0	0	2
-6 04468220E-02	0	0	0	0	0	3
-1 71819541E-02	0	0	0	0	0	4
5 07427C07E-02	0	0	0	0	0	5
-1 14599346E-02	0	0	0	0	0	6
1 05770171E-03	0	C	0	0	0	7
-6 03190684E-05	0	0	0	0	0	8
3 12209663E-05	0	0	0	0	0	9

MODE SHAPE 22

5 48026532E-05	0	0	0	0	0	1
-5 44372392E-02	0	0	0	0	0	2
2 63755849E-02	0	0	0	0	0	3
-4 29737663E-01	0	0	0	0	0	4
1 0CCLC000E 00	0	0	0	0	0	5
-2 13745245E-01	0	0	0	0	0	6
1 87815624E-02	0	0	0	0	0	7
-1 02070825E-03	0	0	0	0	0	8
4 96959200E-04	0	0	0	0	0	9

LINER MODEL NASA VIB TEST K 30000 SIMP SUP ALUM EXIT END

RENORMALIZED MODE SHAPES
(RELATIVE TO A FREE-FREE STRUCTURE)

MODE SHAPE 23

-1 14263016E-05	0	0	0	0	0	1
-1.24019C16E-05	0	0	0	0	0	2
-1 29736211E-05	0	0	0	0	0	3
2 81448405E-04	0	0	0	0	0	4
-2 60560E37E-05	0	0	0	0	0	5
1 23936853E-04	0	0	0	0	0	6
-2 90040E36E-05	0	0	0	0	0	7
-1 30834.27E-05	0	0	0	0	0	8
-1 2741 7C50E-05	0	0	0	0	0	9
-3 23572996E-02	0	0	0	0	0	11
5 53656957E-02	0	0	0	0	0	12
-4 56646931E- 1	0	0	0	0	0	13
1 000000C0E 00	0	0	0	0	0	14
-2 16393501E-01	0	0	0	0	0	15
3 47243053E-02	0	0	0	0	0	16
-6 31662160E-03	0	0	0	0	0	17

LINER MODEL NASA VIB TEST K 30000 SIMP SUP ALUM EXIT END

INTERNAL LOADS DUE TO THE MODAL DEFLECTIONS
(RELATIVE TO A FREE-FREE STRUCTURE)

MODE 1

-9 42434335E 03	-7 2488364CE 03	-7 24883640E 03	-5 75743043E 03	-5 75743043E 03	-3 02322635E 03	6
-3 01276138E 03	-3 012761386 03	-2 98806396E 03	-2 51445502E 03	-1 23607282E 03	-5 61367732E 03	12
-5 66643137E 03	-5 7C212746E 03	-5 76656783E 03	-5 20308781E 03	-3 94426993E 03	-2 55761692E 03	18
-1 26025704E 03	3 86475223E-01	-7 03380913E 00	-1 44096398F 02	0	0	24
2 87171736E 02	-6 76520097E 01	-6 91803098E 01	0	0	-9 42434335E 03	36
-5 61367732E 03	5 86475223E-01					38

MODE 2

-3 98215058E 04	-2 07716192E 04	-2 07716182E 04	-7 88386387E 03	-7 8838638?E 03	1 24386263E 04	6
1 47528574E 04	1 47528574E 04	1 70699807E 04	1 77569111E 04	1 45115404E 04	-2 14812613E 04	12
-1 09487832F 04	-3 81666321F 03	8 61105673E 03	1 14850608E 04	1 72465114E 04	1 95664321F 04	18
1 60144491F 04	-7 17481852E-01	1 4043303CE 03	1 14459048E 03	0	0	24
5 73768127E 1	-8 37343526E 02	-1 29204747E 03	0	0	-3 98215058E 04	36
-2 14812613E 04	-7 17481852E-01					38

MODE 3

1 342900048E 05	4 40461785E 04	4 40461785E 04	-1 23158725E 04	-1 23158725E 04	-4 79483700F 04	6
-4 89353257E 04	-4 89353257E 04	-2 70246330E 04	1 87146276E 04	9 37618399E 04	3 68622884E 04	12
7 79966414E 03	-1 09959908E 04	-4 02651961E 04	-3 18249974E 04	-1 16556652E 04	3 39995024E 04	18
1 84384255E 04	-4 04595840E-01	-3 87501779E 03	2 10729486E 03	0	0	24
6 73800224E 03	2 27233806E 03	-8 56236613E 03	0	0	1 342900048E 05	36
3 68622884E 04	-4 04595840E-01					38

MODE 4

0	0	0	0	1 68418765E 05	1 67889270E 05	24
1 55144325E 05	1 35372433E 05	1 22567365E 05	9 76985860E 04	5 79392809E 04	7 63645679E 03	30

MODE 5

-4 23175681E 05	-8 01342332E 04	-8 01342332E 04	1 02456586E 05	1 02456586E 05	5 65233350E 03	6
-2 07341269E 04	-2 07341269E 04	-8 01214170E 04	-8 45890617E 04	1 24071847E 05	-1 57820438E 04	12
7 57268733E 02	1 08C31556E 04	2 40846002F 04	1 08545361F 04	-1 82129332E 04	-1 69599640E 04	18
-1 58229370E 04	5 13757753E-01	2 20524031E 03	-1 80839443E 03	0	0	24
-7 92384845E 03	5 85238745E 03	-1 96937779E 03	0	0	-4 23175681E 05	36
-1 57820438E 04	5 13757753E-01					38

MODE 6

-6 29626089E 05	-6 12 68256E 04	-6 12368256F 04	1 84101224F 05	1 84101224E 05	-1 95341003E 05	6
-1 78589180E 05	-1 78589180E 05	-3 67895606E 03	2 37209681E 05	-1 84974834E 05	6 47224462E 04	12
-1 52141234E 01	-3 34C54711E 04	-4 99214C41E 04	-3 85005674E 04	-6 63903493E 03	4 87464917F 04	18
5 82061724E 04	-1 31319465E 00	-8 63168275E 03	6 65217030E 03	0	0	24
4 08797254E 03	1 74C64256E 03	-1 42805807E 03	0	0	-6 29626089F 05	36
6 47224462E 04	-1 31319465E 00					38

MODE 7

2 24346790E 04	-1 49380299E 03	-1 49380299E 03	-5 77659839E 03	-5 77659839E 03	1 25279687E 04	6
1 31986821E 04	1 31986821E 04	-6 47437042E 03	-1 54175517E 04	1 16195145E 04	5 91696209E 04	12
-1 21773638E 04	-3 81318587E 04	-5 20248383E 03	-9 90238702E 03	-1 45038635E 04	-3 33613947E 03	18
9 30004013E 04	-1 53965846E 00	-9 51293182F 03	1 06287931E 04	0	0	24
-9 48870277E 03	4 98525610E 03	2 06816769E 04	3 29853492E-03	0	2 24346790E 04	36
5 91696209E 04	-1 53965846E 00					38

LINER MODEL NASA VIB TEST K 30000 SIMP SUP ALUM EXIT END

INTERNAL LOADS DUE TO THE MODAL DEFLECTIONS
(RELATIVE TO A FREE-FREE STRUCTURE)

MODE 8

9 93819320E 03	-7 65582830E 02	-7 65582830E 02	-1 86133957E 03	-1 86133957E 03	1 29520001E 04	6
-1 04309082E 04	-1 04309082E 04	-2 39468059E 04	1 67368858E 04	-5 05287719E 03	-1 26832584E 05	12
2 75951975E 04	7 98825681E 04	-1 34035209E 04	-1 34322365E 04	-3 44366118E 04	-1 31632997E 04	18
4 18578959E 04	-7 03614843E-01	2 06437036E 04	4 78383994E 03	0	0	24
1 99216376E 04	1 28357358E 04	1 01157251E 04	-7 81085253E-03	0	9 93819320E 03	36
-1 26832584E 05	-7 03614843E-01					38

MODE 9

-4 65182787E 05	7 23199832E 04	7 23199832E 04	7 08820069E 04	7 08820069E 04	-2 85010958E 05	6
-4 61404616E 04	-4 61404616E 04	5 43480748E 05	-3 56530091E 05	1 43557985E 05	-3 26401734E 04	12
7 98945913E 03	1 70303491E 04	-3 17220169E 04	3 25608879E 03	5 94977546E 04	-2 51683196E 04	18
4 26502627E 03	-1 50128405E-01	5 41726959E 03	4 87449652E 02	0	0	24
2 95587987E 04	-1 53307380E 04	2 43306631E 04	-1 49557126E-02	0	-4 65182787E 05	36
-3 26401734E 04	-1 50128405E-01					38

MODE 10

0	0	0	0	-4 10028881E 05	-3 92351276E 05	24
-7 77415788E 04	2 24039030E 05	3 85298130E 05	5 67193019E 05	5 39953983E 05	7 83896405E 04	30

MODE 11

2 70957804E 04	-7 51186705E 03	-7 51186705E 03	1 40912798E 03	1 40912798E 03	1 13691567E 04	6
-1 48431620E 04	-1 48431620E 04	-1 20764375E 04	7 55439800E 03	-1 12188844E 03	1 28600027E 05	12
-6 53650782E 04	-1 03547044E 05	6 14423424E 04	8 99766243E 04	7 10208917E 04	3 05362108E 04	18
-1 01840752E 05	9 98222733E-01	-2 63953462E 04	-1 16390574E 04	0	0	24
2 12448013E 04	3 22250274E 04	1 44008070E 04	0	0	2 70957804E 04	36
1 28600027E 05	9 98222733E-01					38

MODE 12

-1 41908249E 06	5 07310987E 05	5 07310987E 05	-2 77779579E 05	-2 77779579E 05	1 21658333E 05	6
1 06880344E 05	1 06880344E 05	-1 06105956E 05	4 57769722E 04	-1 49767709E 04	1 02246061E 04	12
-6 31718462E 03	-7 51762122E 03	9 96969736E 03	7 12075710E 03	-4 26750594E 03	1 79634398E 03	18
-2 51912487E 03	2 35941228E-02	-2 20556486E 03	-2 87902689E 02	0	0	24
-1 35169525E 03	4 45497084E 03	-8 24202704E 02	-6 01199073E-02	0	-1 41908249E 06	36
1 02246061E 04	2 35941228E-02					38

MODE 13

0	0	0	0	5 46226823E 05	4 86704963E 05	24
-4 92831069E 05	-5 06589228E 05	-4 13489467E 05	-1 90038653E 03	5 79823130E 05	1 01882011E 05	30

MODE 14

-1 65145104E 03	8 53950644E 02	8 53950644E 02	-1 00849783E 03	-1 00849783E 03	-3 88690194E 02	6
1 40907907E 04	1 40907907E 04	-7 87052298E 03	-8 98068869E 02	1 46289808E 03	-1 45194425E 05	12
1 18131645E 05	8 31622243E 04	-1 91230538E 05	-1 65116061E 05	3 28815052E 04	2 48636061E 05	18
-2 05034366E 05	1 55655104E 00	3 51101458E 04	-2 34426777E 04	0	0	24
-2 45634048E 04	7 22451413E 03	3 05866995E 04	0	0	-1 65145104E 03	36
-1 45194425E 05	1 55655104E 00					38

MODE 15

0	0	0	0	4 22295934E 05	3 47143239E 05	24
-8 00041425E 05	3 19698489E 05	8 80911434E 05	9 69220030E 05	-8 64602888E 05	-1 90887905E 05	30

MODE 16

0	0	0	0	1 00563808E 05	6 33687848E 04	24
-3 86028522E 05	1 29310313E 06	1 41970919E 06	-1 27879466E 06	2 74048987E 05	2 33684003E 05	30

MODE 17

1 48557211E 05	-1 59727770E 05	-1 59727770E 05	2 83202177E 05	2 83202177E 05	-8 12205184E 05	6
1 77398126E 06	1 77398126E 06	-6 98378676E 05	1 89635475E 05	-5 11758763E 04	1 18980023E 04	12
-1 38277332E 04	4 76951325F 03	1 83304463E 03	8 70283628E 03	-3 96180546E 03	-1 90980153E 03	18
8 65799010E 02	0	-3 43005666E 03	9 89439321E 01	0	0	24
1 51937551E 04	7 13764179E 03	-1 22332810E 03	1 67116019E-02	0	1 48557211E 05	36
1 18980023E 04	0					38

MODE 18

0	0	0	0	-2 88312954E 03	-1 59225586E 03	24
1 23548377E 04	-5 54382414E 04	-5 05390382E 04	8 34206140E 04	-1 50359745E 05	7 94642025E 05	30

MODE 19

-2 00104171E 02	4 65121228E 01	4 65121228E 01	-4 02665001E 01	-4 02665001E 01	-3 83021492E 02	6
6 03317481E 03	6 03317481E 03	-6 33273500E 03	3 12554911E 03	-1 02295551E 03	-4 47065753E 05	12
5 29284191E 05	-2 56001973E 05	-1 52042471E 05	6 48389947E 04	4 39162546E 05	-3 24932915E 05	18
1 36970481E 05	-7 78075731E-01	1 30179989E 05	1 56538591E 04	0	0	24
-1 25562841E 04	2 73523220E 04	-1 52754942E 04	-2 97342619E-02	0	-2 00104171E 02	36
-4 47065753E 05	-7 78075731E-01					38

MODE 20

-3 19554607E 02	5 77907944E 02	5 77907944E 02	-1 14735092E 03	-1 14735092E 03	2 92710000E 03	6
-2 18972304E 03	-2 18972304E 03	-2 02457958E 03	1 42479245E 03	-4 69969779E 02	4 78845537E 05	12
-6 25853252E 05	6 20624399E 05	-5 46318871E 05	-2 78935900E 05	6 30189759E 05	-3 47782448E 05	18
1 27916761E 05	-6 74485993E-01	-1 47293188E 05	1 46191369E 04	0	0	24
-2 11247459E 04	3 01763022E 04	-1 17453925E 04	1 92238881E-02	0	-3 19554607E 02	36
4 78845537E 05	-6 74485993E-01					38

LINER MODEL NASA V1B TEST K 30000 SIMP SUP ALUM EXIT END

INTERNAL LOADS DUE TO THE MODAL DEFLECTIONS
(RELATIVE TO A FREE-FREE STRUCTURE)

MODE 21

0	0	0	0	4 99970746E 06	-5 79242557E 05	24
2 17182487E 04	1 58949803E 05	-8 17985225E 04	1 13708447E 04	-7 33492720E 02	6 17816955E 01	30

MODE 22

0	0	0	0	-2 71733561E 05	4 40729493E 04	24
-2 28603253E 05	3 34048516E 06	-1 59309466E 06	2 10531086E 05	-1 29712366E 04	1 02256452E 03	30

MODE 23

-1 09212774E 01	3 29167387E 01	3 29167387E 01	-6 90745234E 01	-6 90745234E 01	1 83557568E 02	6
-3 35575384E 02	-3 35575384E 02	1 35724016E 02	-4 69484913E 01	1 05079472E 01	6 61105645E 04	12
-1 20422225E 05	4 10642385E 05	-1 04787518E 06	1 99486390E 06	-7 56536347E 05	2 03049824E 05	18
-5 45300812E 04	2 39717481E-01	-2 48710635E 04	-6 23202991E 03	0	0	24
-1 37075752E 04	-6 49564570E 03	1 04230320E 03	0	0	-1 09212774E 01	36
6 61105645E 04	2 39717481E-01					38

LINER MODEL NASA V1B TEST K 30000 SIMP SUP ALUM EXIT END

MATRIX OF STATIC + PRESSURE LOADS EXTERNALLY APPLIED AT THE DEGREES OF FREEDOM

LOADING CONDITION 1

2 02641957E 03	0	0	0	0	1

SUMMATION OF THE TRANSLATIONAL AND ROTATIONAL LOADS

2 02641957E 03	0	0	0	0	

LOADING CONDITION 2

1 01581495E 03	0	0	0	0	1
1 01581495E 03	0	0	0	0	9

SUMMATION OF THE TRANSLATIONAL AND ROTATIONAL LOADS

2 03162990E 03	0	0	0	0	

2 LOADING CONDITIONS HAVE BEEN SUCCESSFULLY SPECIFIED

LINER MODEL NASA V1B TEST K 30000 SIMP SUP ALUM EXIT END

INTERNAL LOADS DUE TO STATIC + PRESSURE LOADS EXTERNALLY APPLIED AT THE DEGREES OF FREEDOM
(RELATIVE TO A FREE-FREE STRUCTURE)

STATIC OR PRESSURE LOAD 1

0	0	0	0	-2 64199993E 01	-2 40799993E 01	24
-1 99099995E 01	-1 65599996E 01	-1 45699997E 01	-1 11599997E 01	-6 35999990E 00	-8 29999983E-01	30

STATIC OR PRESSURE LOAD 2

3 24683639E 01	-3 24469301E 01	-3 24469301E 01	-6 48209614E 01	-6 48209614E 01	-8 48021722E 01	6
-9 11947560E 01	-9 11947560E 01	-9 65219486E 01	-9 16710818E 01	-6 97731239E 01	-7 94658989E 00	12
-4 67739534E 01	-7 18927646E 01	-1 14674148E 02	-1 14474463E 02	-1 13353793E 02	-1 00457039E 02	18
-5 12492555E 01	1 08980839E-02	-5 17699873E 00	-5 85830432E 00	0	0	24
4 40457332E 00	1 48401508E 00	3 12270105E 00	0	0	3 24683639E 01	36
-7 94658989E 00	1 08980839E-02					38

LINER MODEL NASA VIB TEST K 30000 SIMP SUP ALUM EXIT END

DEFLECTIONS DUE TO STATIC + PRESSURE LOADS EXTERNALLY APPLIED AT THE DEGREES OF FREEDOM
(RELATIVE TO A FREE-FREE STRUCTURE)

STATIC OR PRESSURE LOAD 1

0	0	0	0	0	0	6
0	0	0	0	0	0	12
0	0	0	0	1.21952921E-06	-4.07435256E-06	18
-4.81923515E-05	-8.78652642E-05	-9.49673080E-05	-1.06055324E-04	-1.18350239E-04	-1.28051932E-04	24
-1.29282865E-04						25

STATIC OR PRESSURE LOAD 2

-1.44123693E-02	-1.44263382E-02	-1.40616354E-02	-1.13654479E-02	-1.04391824E-02	-7.93701298E-03	6
-3.27348146E-03	5.04365885E-03	1.45925336E-02	-1.42405869E-02	-1.37206134E-02	-1.12186179E-02	12
-1.03777332E-02	-7.98254488E-03	-3.16939151E-03	5.24782860E-03	0	0	18
0	0	0	0	0	0	24
0						25

LINER MODEL NASA VIB TEST K 30000 SIMP SUP ALUM EXIT END

TOTAL FORCES AND MOMENTS ABOUT THE ORIGIN

STATIC OR PRESSURE LOAD 1

2.02641997E 03 0

STATIC OR PRESSURE LOAD 2

0 2.03162998E 03

LINER MODEL NASA VIB TEST K 30000 SIMP SUP ALUM EXIT END

STATIC + PRESSURE LOAD DISTRIBUTION (INCLUDING INERTIA REACTIONS) ON THE FREE-FREE STRUCTURE

STATIC OR PRESSURE LOAD 1

0	0	0	0	0	0	6
0	0	0	0	0	0	12
0	0	0	0	2.64199994E 01	-2.33999997E 00	18
-4.16999990E 00	-3.34999996E 00	-1.98999998E 00	-3.40999997E 00	-4.79999995E 00	-5.52999991E 00	24
-8.29999983E-01						25

STATIC OR PRESSURE LOAD 2

1.38323732E 01	-2.34463930E 00	-4.17826748E 00	-3.35664180E 00	-1.99394540E 00	-3.41676071E 00	6
-4.80951655E 00	-5.54096383E 00	1.38323732E 01	-2.80555132E-01	-3.30654263E-01	-2.60515481E-01	12
-1.50297341E-01	-2.50495657E-01	-3.69713741E-01	-3.90773216E-01	0	0	18
0	0	0	0	0	0	24
0						25

LINER MODEL NASA VIB TEST K 30000 SIMP SUP ALUM EXIT END

DIAGONAL STRESS CONVERSION MATRIX

1.51998784E 00	1.51998784E 00	1.91058463E 01	1.91058463E 01	1.91058463E 01	1.91058463E 01	6
1.91058463E 01	1.91058463E 01	1.91058463E 01	1.91058463E 01	1.91058463E 01	3.65497079E 00	12
3.65497079E 00	3.65497079E 00	3.65497079E 00	3.65497079E 00	3.65497079E 00	3.65497079E 00	18
3.65497079E 00	3.65497079E 00	0	0	7.47943151E-01	0.99999999E 01	24
0.99999999E 01	0.99999999E 01	0.99999999E 01	0.99999999E 01	0.99999999E 01	0.99999999E 01	30
3.33333331E-05	3.33333331E-05	3.33333331E-05	0	0	0	36
0	0					38

THE ORDER OF THIS MATRIX IS 39 X 38

LINER MODEL NASA V18 TEST K 30000 SIMP SUP ALUM EXIT END

STRESSES DUE TO UNIT LOADS EXTERNALLY APPLIED AT THE DEGREES OF FREEDOM
(RELATIVE TO A FREE-FREE STRUCTURE)

DEGREE OF FREEDOM 1

2 51593834E 01	1 92808381E 01	2 42355055E 02	1 91926196E 02	1 91926196E 02	1 00185528E 02	6
9 97665453E 01	9 97665453E 01	9 89148080E 01	8 31783020E 01	4 07722032E 01	3 59418216E 01	12
3 61846795E 01	3 63532987E 01	3 66669491E 01	3 30627143E 01	2 50126758E 01	1 61763616E 01	18
[illegible]	-3 73233941E-03	0	0	0	0	24
-1 66630992E-05	3 94894174E-06	4 07557136E-06	0	0	0	36

DEGREE OF FREEDOM 2

1 43112798E 01	1 96024543E 01	2 46397683E 02	1 93989728E 02	1 93989728E 02	9 86342216E 01	6
9 84993553E 01	9 84993553E 01	9 82822835E 01	8 31716764E 01	4 07689369E 01	3 46149769E 01	12
3 54112986E 01	3 59585705E 01	3 69637433E 01	3 33051568E 01	2 51337066E 01	1 61776572E 01	18
7 96990442E 00	-3 70437652E-03	0	0	0	0	24
-1 75827819E-05	4 02755439E-06	4 24291760E-06	-0	0	0	36

DEGREE OF FREEDOM 3

9 17615497E 00	1 35559547E 01	1 70394778E 02	2 08164090E 02	2 08164090E 02	9 84965491E 01	6
9 80363083E 01	9 80363083E 01	9 70924115E 01	8 28497767E 01	4 06102544E 01	2 82131237E 01	12
3 12009409E 01	3 32471964E 01	3 69902790E 01	3 33939365E 01	2 53615290E 01	1 62394352E 01	18
8 00045884E 00	-3 50609954E-03	0	0	0	0	24
-1 99652196E-05	3 51215973E-06	4 44425100E-06	0	0	0	36

DEGREE OF FREEDOM 4

3 37434176E 00	5 78922254E 00	7 27690005E 01	9 36445308E 01	9 36445308E 01	1 32142094E 02	6
1 22782145E 02	1 22782145E 02	1 01957801E 02	8 04843259E 01	3 94441870E 01	7 91804206E 00	12
1 56307128E 01	2 09087654E 01	3 05547699E 01	2 86609519E 01	2 44316965E 01	1 66928715E 01	18
8 22445142E 00	-2 58361548E-03	0	0	0	0	24
-1 79857545E-05	-2 27189702E-06	2 27091652E-06	0	0	0	36

DEGREE OF FREEDOM 5

1 86456731E 00	4 21509403E 00	5 29826200E 01	7 33048564E 01	7 33048564E 01	1 10791820E 02	6
1 35760103E 02	1 35760103E 02	1 05833974E 02	7 96852505E 01	3 90502769E 01	4 20222765E 00	12
1 20696437E 01	1 74435452E 01	2 72928748E 01	2 61785173E 01	2 36904442E 01	1 68459994E 01	18
8 30007100E 00	-2 31953630E-03	0	0	0	0	24
-1 46372706E-05	-4 55366707E-06	9 37489831E-07	0	0	0	36

DEGREE OF FREEDOM 6

-1 99219455E 00	6 34282213E-01	7 97276037E 00	3 06675309E 01	3 06675309E 01	7 24879533E 01	6
8 80081010E 01	6 80081010E 01	1 22761686E 02	7 92015702E 01	3 88118422E 01	-2 93393451E 00	12
4 26993132E 00	9 19996452E 00	1 82102972E 01	1 89033785E 01	2 04528195E 01	1 69391944E 01	18
8 34634984E 00	-1 65335752E-03	0	0	0	0	24
-5 62947345E-06	-8 08119023E-06	-3 78344765E-06	0	0	-0	36

DEGREE OF FREEDOM 7

-8 11347602E 00	-4 67000896E 00	-5 87007809E 01	-2 89817473E 01	-2 89817473E 01	2 56685647E 01	6
3 28513658E 01	3 28513658E 01	4 89807236E 01	9 06645274E 01	4 44625962E 01	-1 19708003E 01	12
-6 73148274E 00	-3 14520034E 00	3 41075876E 00	5 69878465E 00	1 08110622E 01	1 47474852E 01	18
7 26652229E 00	-4 85128140E-04	0	0	0	0	24
3 95617794E-06	-4 86496264E-06	-1 31097320E-05	0	0	-0	36

DEGREE OF FREEDOM 8

-1 67348281E 01	-1 20896478E 01	-1 51963685E 02	-1 11912709E 02	-1 11912709E 02	-3 83909890E 01	6
-3 63068426E 01	-3 63068426E 01	-3 15670151E 01	-1 57965061E 01	7 67471802E 01	-2 41325617E 01	12
-2 17828828E 01	-2 01731151E 01	-1 72272812E 01	-1 39638777E 01	-6 67276973E 00	2 22089666E 00	18
1 09247112E 00	1 54230805E-03	0	0	0	0	24
1 19355768E-05	-2 33516619E-06	-1 36278871E-05	0	0	-0	36

DEGREE OF FREEDOM 9

-2 51108003E 01	-1 93293892E 01	-2 42965326E 02	-1 93145373E 02	-1 93145373E 02	-1 01780520E 02	6
-1 01481773E 02	-1 01481773E 02	-1 00730231E 02	-8 49024880E 01	-4 20845234E 01	-3 59704143E 01	12
-3 63529259E 01	-3 66119739E 01	-3 70795542E 01	-3 34746009E 01	-2 54205304E 01	-1 65378128E 01	18
-8 15364981E 00	3 77155146E-03	-0	-0	0	0	24
1 68076327E-05	-3 90024471E-06	-3 97310185E-06	0	0	-0	36

DEGREE OF FREEDOM 10

2 16388831E 01	1 72289588E 01	2 16563469E 02	1 78761375E 02	1 78761375E 02	1 10083622E 02	6
1 07852028E 02	1 07852028E 02	1 02951218E 02	8 32215238E 01	4 07935095E 01	1 69950774E 01	12
4 11187124E 01	3 88718668E 01	3 47735545E 01	3 15160745E 01	2 42406279E 01	1 61682159E 01	18
7 96529788E 00	-3 61019900E-03	0	0	0	0	24
1 07955156E-05	3 44741851E-06	3 00800669E-06	-0	0	0	36

DEGREE OF FREEDOM 11

1 63310213E 01	1 40002039E 01	1 75978872E 02	1 56052318E 02	1 56052318E 02	1 20024428E 02	6
1 16210304E 02	1 16210304E 02	1 07774390E 02	8 34836280E 01	4 09227163E 01	1 10086299E 01	12
3 01328331E 01	4 32163763E 01	3 28721061E 01	2 99173662E 01	2 33181897E 01	1 61183146E 01	18
7 94082022E 00	-3 37039179E-03	0	0	0	0	24
-3 34258077E-06	3 29802960E-06	1 80953252E-06	-0	0	0	36

DEGREE OF FREEDOM 12

4 77513272E 00	6 24121153E 00	7 84503835E 01	9 11683989E 01	9 11683989E 01	1 14766175E 02	6
1 13717367E 02	1 13717367E 02	1 11458708E 02	8 51175451E 01	4 17281681E 01	4 54972899E 00	12
1 45438941E 01	2 13824916E 01	3 38788387E 01	3 03950900E 01	2 26141980E 01	1 58065671E 01	18
7 78755897E 00	-2 54781631E-03	0	0	0	0	24
5 35926604E-06	6 24865562E-06	1 41978343E-06	-0	0	0	36

LINER MODEL NASA V1B TEST K 30000 SIMP SUP ALUM EXIT END

STRESSES DUE TO UNIT LOADS EXTERNALLY APPLIED AT THE DEGREES OF FREEDOM
(RELATIVE TO A FREE-FREE STRUCTURE)

DEGREE OF FREEDOM 13

2 49942642E 00	4 50638402E 00	5 66440582E 01	7 40123904E 01	7 40123904E 01	1 06104015E 02	6
1 07307309E 02	1 07307309E 02	1 10079463E 02	8 56918597E 01	4 20112813E 01	2 67566034E 00	12
1 13692255E 01	1 73182136E 01	2 81896770E 01	3 16215900E 01	2 28782970E 01	1 56969479E 01	18
7 7336+705E 00	-2 29985514E-03	0	0	0	0	24
4 98598707E-06	7 67913928E-06	2 00058872E-06	-0	0	0	36

DEGREE OF FREEDOM 14

-2 15839240E 00	0 88579476E-01	8 65526247E 00	3 32457817E 01	3 32457817E 01	7 85288137E 01	6
8 49753618E 01	8 49753618E 01	9 94600606E 01	8 57516265E 01	4 20407438E 01	-2 53429878E 00	12
4 13936329E 00	8 70673668E 00	1 70546682E 01	1 94835402E 01	2 49104428E 01	1 56861557E 01	18
7 72865224E 00	-1 65835662E-03	0	0	0	0	24
2 89107823E-06	9 36382067E-06	4 87286234E-06	-0	0	-0	36

DEGREE OF FREEDOM 15

-8 38337469E 00	-4 72224486E 00	-5 93573725E 01	-2 77669650E 01	-2 77669650E 01	3 03014338E 01	6
3 91980413E 01	3 91980413E 01	5 91557539E 01	7 41314054E 01	3 63124654E 01	-1 13218665E 01	12
-6 60593522E 00	-3 37764889E 00	2 52442647E 00	4 48459899E 00	8 86450779E 00	1 79102321E 01	18
8 82559288E 00	-5 44201863E-04	0	0	0	0	24
3 14504278E-06	3 79135239E-06	1 14298001E-05	0	0	-0	36

DEGREE OF FREEDOM 16

-1 08621100E 01	-1 21413666E 01	-1 52616291E 02	-1 11917314E 02	-1 11917314E 02	-3 72120124E 01	6
-3 11270061E 01	-3 11270061E 01	-1 74499358E 01	1 02854486E 01	4 83718425E 00	-2 38266787E 01	12
-2 16582337E 01	-2 01724235E 01	-1 74530147E 01	-1 49549790E 01	-9 37357652E 00	-2 76805881E 00	18
1 43487444E 01	1 34928338E-03	0	0	0	0	24
8 08236696E-06	-2 07289550E-06	8 57772565E-06	0	0	-0	36

DEGREE OF FREEDOM 17

0	0	0	0	-9 75151145E-03	-1 18830250E-01	24
-9 82520878E-02	-8 17204714E-02	-7 19001979E-02	-5 50724918E-02	-3 13853982E-02	-4 09589314E-03	30

DEGREE OF FREEDOM 18

0	0	0	0	7 38191640E-01	-1 18830250E-01	24
-9 82520878E-02	-8 17204714E-02	-7 19001979E-02	-5 50724918E-02	-3 13853982E-02	-4 09589314E-03	30

DEGREE OF FREEDOM 19

0	0	0	0	7 38191640E-01	9 88116980E 00	24
-9 82520878E-02	-8 17204714E-02	-7 19001979E-02	-5 50724918E-02	-3 13853982E-02	-4 09589314E-03	30

DEGREE OF FREEDOM 20

0	0	0	0	7 38191640E-01	9 88116968E 00	24
9 90174782E 00	-8 17204714E-02	-7 19001979E-02	-5 50724918E-02	-3 13853982E-02	-4 09589314E-03	30

DEGREE OF FREEDOM 21

0	0	0	0	7 38191640E-01	9 88116980E 00	24
9 90174782E 00	9 91827953E 00	-7 19001979E-02	-5 50724918E-02	-3 13853982E-02	-4 09589314E-03	30

DEGREE OF FREEDOM 22

0	0	0	0	7 38191640E-01	9 88116968E 00	24
9 90174782E 00	9 91827941E 00	9 92809975E 00	-5 50724918E-02	-3 13853982E-02	-4 09589314E-03	30

DEGREE OF FREEDOM 23

0	0	0	0	7 38191640E-01	9 88116968E 00	24
9 90174782E 00	9 91827941E 00	9 92809975E 00	9 94492745E 00	-3 13853982E-02	-4 09589314E-03	30

DEGREE OF FREEDOM 24

0	0	0	0	7 38191640E-01	9 88116968E 00	24
9 90174782E 00	9 91827941E 00	9 92809963E 00	9 94492745E 00	9 96861458E 00	-4 09589314E-03	30

DEGREE OF FREEDOM 25

0	0	0	0	7 38191640E-01	9 88116980E 00	24
9 90174782E 00	9 91827953E 00	9 92809975E 00	9 94492745E 00	9 96861458E 00	9 99590409E 00	30

LINER MODEL NASA VIB TEST K 30000 SIMP SUP ALUM EXIT END

STRESSES DUE TO THE STATIC AND PRESSURE LOADS EXTERNALLY APPLIED AT THE DEGREES OF FREEDOM (RELATIVE TO A FREE-FREE STRUCTURE)

STATIC OR PRESSURE LOAD 1

0	0	0	0	-1 97606577E 01	-2 40799993E 02	24
-1 99099994E 02	-1 65599996E 02	-1 45699996E 02	-1 11599998E 02	-6 35999984E 01	-8 29999983E 00	30

STATIC OR PRESSURE LOAD 2

4 93515182E 01	-4 93189389E 01	-6 19926059E 02	-1 23945033E 03	-1 23845933E 03	-1 62021729E 03	6
-1 74235299E 03	-1 74235299E 03	-1 84413354E 03	-1 75145361E 03	-1 33307460E 03	-2 90445536E 01	12
-1 70957580E 02	-2 62765953E 02	-4 19130659E 02	-4 18400818E 02	-4 14304805E 02	-3 67167544E 02	18
-1 87314533E 02	3 98321778E-02	-0	-0	0	0	24
1 46819109E-04	4 94671685E-05	1 04090033E-04	0	0	0	36

END

ILL INPUT CHAR ABOVE 001045

USE ENTRY POINT 81 FOR THE NEXT RUN

FINAL TIME 00 421 DATE 1 /28/65

SOLUTION OF N SECOND-ORDER SIMULTANEOUS DIFFERENTIAL EQUATIONS WITH TIME DEPENDENT INPUTS

TASK 2.8 U.K 3L00C.E-55 ALUM. INITIAL CCAC. 0.0 0000000000000000000000000000000000000000000000000000000000000000

RUN 1 HAS 16 SIMULTANEOUS DIFFERENTIAL EQUATIONS. 1 TIME DEPENDENT INPUTS. 16 STATIONS

REGULAR PRINT INTERVALS USE TOLERANCE TO FIX DELTA T SOLVE ALL EQUATIONS
PRINT SOLUTION TO ALL EQUATIONS PRINT WITHOUT HEADINGS PRINT XI DOUBLE DOT,XI DOT,XI

(T)I = 0 (T)F = 0 18000000E-00 (T)R = 0 09999999E 01

(DELTA T)O = 0 99999999E-05 (DELTA T)MIN = 0 99999999E-07 (DELTA T)MAX = 0 99999999E-03

(MAXLM)	(MINLM)	(TOLER)	(XI)	(XI)
0.99999999E 38	-0.99999999E 38	0.99999999E-03	0.	0
0 99999999E 38	-0 99999999E 38	0 99999999E-03	0	0
0.99999999E 38	-0.99999999E 38	0.99999999E-03	0	0
0 99999999E 38	-0 99999999E 38	0 99999999E-03	0	0
0.99999999E 38	-0.99999999E 38	0.99999999E-03	0	0
0 99999999E 38	-0 99999999E 38	0 99999999E-03	0	0
0.99999999E 38	-0.99999999E 38	0.99999999E-03	0	0
0 99999999E 38	-0 99999999E 38	0 99999999E-03	0	0
0.99999999E 38	-0.99999999E 38	0.99999999E-03	0	0
0 99999999E 38	-0 99999999E 38	0 99999999E-03	0	0
0.99999999E 38	-0.99999999E 38	0.99999999E-03	0	0
0 99999999E 38	-0 99999999E 38	0 99999999E-03	0	0
0.99999999E 38	-0.99999999E 38	0.99999999E-03	0	0
0 99999999E 38	-0 99999999E 38	0 99999999E-03	0	0
0.99999999E 38	-0.99999999E 38	0.99999999E-03	0	0
0 99999999E 38	-0 99999999E 38	0 99999999E-03	0	0

COEFFICIENT OF LHS OF MOTION EQUATIONS

LHS MOTION EQUATION 1

0 25506736E 01	0	0	0	0	0
0	0	0	0	0	0
0.	0	0	0		
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0		
0 25E75728E 06	-0 24162888E 06	0 55675939E 05	-0 20793521E 05	0 14068533E 05	-0 13177758E 04
0 20302167E 03	-0 35017187E 02	0 10114157E 02	-0 11153068E 06	0 53302231E 05	-0 16161907E 05
0 10735668E 05	-0 89738461E 03	0 13841627E 03	-0 23933709E 02		

SOLUTION OF N SECCAC-CRDER SIMULTANEOUS DIFFERENTIAL EQUATIONS WITH TIME DEPENDENT INPUTS

LHS MOTION EQUATION 2

0	0 60621760E-02	0	0	0	0
0	0	0	0	0	0
0	0	0	0		
0	0	0	0	0	0
0	0	0	0	0	0
0	C	0	0		
-0 241628ESE 06	0 36719833E 06	-0 15764864E 06	0 84769942E 05	-0 57353482E 05	0 53721568E 04
-0 827879?7E 03	0 14306711E 03	-0 24597213E 02	0 41525599E-01	-0 11297669E-00	0 89544269E 00
-0 13187806E 01	0 64037549E 00	-0 19177420E-00	0 22749399E-01		

LHS MOTION EQUATION 3

0	0	0 10803109E-01	0	0	0
0	0	0	0	0	0
0	0	0	0		
0	0	0	0	0	0
0	0	0	0	0	0
0	C	0	0		
0 5567?939E 05	-0 15764864E 06	0 14703602E 06	-0 15046678E 06	0 11473066E 06	-0 10746414E 05
0 16?62703E 04	-0 28643105E C3	0 49297987E 02	0 30474199E-01	-0 12880000E-01	0 69251599E-01
-0 1231273CE-00	0 17450999E-00	-0 14488640E-00	0 67218100E-01		

LHS MOTION EQUATION 4

0.	0	0	0 86787563E-02	0	0
0	0	0	0	0	0
0.	0	0	0		
0.	0	0	0	0	0
0	C	0	0	0	0
0.	0	0	0		
-0 207935?1E C5	0 84769942E C5	-0 15046678E 06	0 83926293E 06	-0 95803080E 06	0 27105284E 06
-0 417750?6E 05	0 72248230E 04	-0 12440226E 04	-0 18296960E-00	0 71158700E-01	-0 30000871E 05
0 15C55464E 01	-0 15080129E C1	0 95642760E 00	-0 32736889E-00		

LHS MOTION EQUATION 5

0	0	0	0	0 51554403E-02	0
0	0	0	0	0	0
0	0	0	0		
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0		
0.140?8533E 05	-0 57353482E C5	0 11473066E 06	-0 95803080E 06	0 12775841E 07	-0 48368982E 06
0 108177?4E 06	-0 18709118E 05	0 32216854E 04	0 20041220E-00	-0 32641299E-01	0 74896879E 00
-0 13?730?5E C1	0 15456842E 01	-0 97500999E 00	0 26401360E-00		

LHS MOTION EQUATION 6

0	0	0	0	0	0 88341967E-02
0	0	0	0	0	0
0	0	0	0		
0	0	0	0	0	0
0	C	0	0	0	0
0	0	0	0		
-0 13177758E 04	0 53721568E 04	-0 10746414E 05	0 27105284E 06	-0 48368982E 06	0 36030331E 06
-0 14153443E C6	0 36917377E C5	-0 63573122E 04	0 23257399E-01	-0 19856279E-00	0 11628903E 01
-0.1432843?E C1	-0.29999630E C5	0.25682700E-01	0.10176550E-00		

LHS MOTION EQUATION 7

0.	0.	0.	0.	0.	0.
0 1?435222E-01	0	0	0	0	0
0.	0.	0.	0.		
0.	0.	0.	0.	0.	0
0	0	0	0	0	0
0.	0.	0.	0.		
0.20302167E 03	-0.82787977E 03	0.16562703E 04	-0.41775066E 05	0 10817774E 06	-0 14153443E 06
0 14624847E C6	-0 56552183E 05	0 14404324E 05	-0 76308199E-01	0 20022070E-00	-0 12813868E 01
0.16305862E C1	-0.67466050E 00	-0.29999895E 05	-0.17408980E-00		

SOLUTION OF N SECOND-ORDER SIMULTANEOUS DIFFERENTIAL EQUATIONS WITH TIME DEPENDENT INPUTS

LHS MOTION EQUATION 8

0.	0.	0.	0	0	0
0	0 14326424E-01	0	0	0	0
0.	0.	0.	0		
0.	0.	0.	0	0	0
0	0	0	0	0	0
0.	0.	0.	0		
-0.35C17187E 02	0.14366711E 03	-0.28643105E 03	0.72248230E 04	-0 18709118E 05	0 36917377E 05
-0 56.52183E 05	0 49241734E 05	-0 17944477E 05	0 49536099E-01	-0 12880540E-00	0 10148159E 01
-0.13416249E 01	0.68C083C0E 00	-0.16128170E-00	0.11232280E-00		

LHS MOTION EQUATION 9

0.	0.	0	0	0	0
0	0	0 25906736E 01	0	0	0
0.	0.	0	0		
0.	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0		
0 10114157E 02	-0 24597213E 02	0 49297987E 02	-0 12440226E 04	0 32216854E 04	-0 63573122E 04
0 14404324E 05	-0 17944477E 05	0 16085576E 05	-0 24933445E 02	0 57324398E 02	-0 14047252E 04
0 35C66818E 04	-0 66644507E 04	0 14973482E 05	-0 18643967E 05		

LHS MOTION EQUATION 10

0	0	0	0	0	0
0	0	0	0 72538857E-03	0	0
0	0	0	0		
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0		
-0 111C3068E 06	0 41525595E-01	0 30474199E-01	-0 18296960E-00	0 20041220E-00	0 23257399E-01
-0 763G8159E-01	0 49536099E-01	-0 24933450E-00	0 24499832E 06	-0 17109107E 06	0 97957990E 05
-0 69C522C6E 05	0 54353207E 04	-0 83762677E 03	0 14480688E 03		

LHS MOTION EQUATION 11

0	0	0	0	0	0
0	0	0	0	0 85492225E-03	0
0	0	0	0		
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0		
0 53.02231E 05	-0 11297665E-00	-0 12886000E-01	0 71158700E-01	-0 32641299E-01	-0 19856279E-00
0 20L2207JE-00	-0 12880540E-00	0 57324398E 02	-0 17109107E 06	0 17931940E 06	-0 20020422E 06
0 149516B4E 06	-0 12492716E 05	0 19253012E 04	-0 33286390E 03		

LHS MOTION EQUATION 12

0	0	0	0	0	0
0	0	0	0	0	0 67357511E-03
0.	0	0	0		
0.	0	0	0	0	0
0	0	0	0	0	0
0.	0	0	0		
-0.1616157E 05	0 89544260E 00	0 69251699E-01	-0 30000871E 05	0 74896870E 00	0 11628905E 01
-0 12813868E 01	0 10148159E 01	-0 14047252E 04	0 97957990E 05	-0 20020422E 06	0 10186099E 07
-0 113E8277E 07	0 30603922E 06	-0 47167C72E 05	0 81567831E 04		

LHS MOTION EQUATION 13

0	0	0	0	0	0
0	0	0	0	0	0
0 38E6C1C2E-03	0	0	0		
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0		
0 107335c8E 05	-0 13167806E-01	-0 12372730E-00	0 15059464E 01	-0 13773099E 01	-0 14378434E 01
0 16.058C2E 01	-0 13416249E 01	0 35066818E 04	-0 65052206E 05	0 14951684E 06	-0 11358277E 07
0.1417C265E 07	-0 53728347E 06	0 11774521E 06	-0 20362932E 05		

SOLUTION OF N SECOND-ORDER SIMULTANEOUS DIFFERENTIAL EQUATIONS WITH TIME DEPENDENT INPUTS

LHS MOTION EQUATION 14

0	0	0	0	0	0
0	0	0	0	0	0
0	0 64766838E-03	0	0		
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0		
-0 89738461E 03	0 64037549E 00	0 17450999E-00	-0 15080131E 01	0 15456842E 01	-0 29999630E 05
-0.67466050E 00	0 68008300E 00	-0 66644507E 04	0 54353207E 04	-0 12492716E 05	0 30603922E 06
-0 5374B347E C6	0 386212S7E C6	-0 14905134E 06	0 38700608E 05		

LHS MOTION EQUATION 15

0.	0.	0.	0.	0.	0.
0	0	0	0	0	0
0.	0.	0.93264247E-03	0.		
0.	0.	0.	0.	0.	0.
0	0	0	0	0	0
0.	0.	0.	0.		
0.13841627E 03	-0.19177420E-00	-0.14488640E-00	0.95642760E 00	-0 97500999E 00	0 29682700E-01
-0 29559855E C5	-0 16128170E-00	0 14973482E 05	-0 83762877E 03	0 19253012E 04	-0 47167072E 05
0.11474521E C6	-0.149051S4E C6	0.15107823E 06	-0.58804228E 05		

LHS MOTION EQUATION 16

0.	0.	0.	0	0	0
0	0	0	0	0	0
0.	0.	0.	0 10103627E-02		
0.	0.	0.	0	0	0
0	0	0	0	0	0
0.	0.	0.	0.		
-0.2353337CSE 02	0.2274S3S5E-01	0.67218100E-01	-0 32736889E-00	0 26401360E-00	0 10176550E-00
-0 17408980E-00	0 11232280E-C0	-0 18643967E 05	0 14480688E 03	-0 33286390E 03	0 81567831E 04
-0.20362S32E 05	0.387006C8E 05	-0.588042S8E 05	0 51165661E 05		

COEFFICIENT OF RHS OF MOTION EQUATIONS

RHS MOTION EQUATION 1

0 10138000E 04

RHS MOTION EQUATION 2

0

RHS MOTION EQUATION 3

0

RHS MOTION EQUATION 4

0

RHS MOTION EQUATION 5

0

RHS MOTION EQUATION 6

0

RHS MOTION EQUATION 7

0.

RHS MOTION EQUATION 8

0

RHS MOTION EQUATION 9

0 10138000E 04

RHS MOTION EQUATION 10

0

SOLUTION OF N SECOND-ORDER SIMULTANEOUS DIFFERENTIAL EQUATIONS WITH TIME DEPENDENT INPUTS

RHS MOTION EQUATION 11

0

RHS MOTION EQUATION 12

0

RHS MOTION EQUATION 13

0

RHS MOTION EQUATION 14

0

RHS MOTION EQUATION 15

0

RHS MOTION EQUATION 16

0

INPUT FOR ADDITIONAL EQUATIONS

COEFFICIENT OF ADDITIONAL EQUATIONS-STATION 1

0.19157600E 07	-0 20974199E 07	0 21156700E 06	-0 79018299E 05	0 53464099E 05	-0 50082699E 04
0 77091359E 03	-0 13220099E 03	0 55665199E 03	-0 57162499E 00	0 12195399E 01	-0 93828100E 01
0 14179700E 02	-0 74062499E 01	0 26171500E 01	-0 58593800E 00		
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0		
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0		
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0		

COEFFICIENT OF ADDITIONAL EQUATIONS-STATION 2

-0.29379259E 06	0.65712500E 06	-0.42313400E 06	0.15802699E 06	-0.10691800E 06	0 10014699E 05
-0 15434399E 04	0 26690699E 03	0 37936900E 03	0 17865000E-00	-0 53131100E-01	0 72949199E 00
-0.14023355E 00	0.29687500E-00	-0.10156300E-00	-0.23437500E-01		
0.	0.	0.	0.	0	0
0	0	0	0	0	0
0.	0.	0.	0.		
0.	0.	0.	0	0	0
0	0	0	0	0	0
0.	0.	0.	0.		
0.	0.	0.	0.	0	0
0	0	0	0	0	0
0.	0.	0.	0		

COEFFICIENT OF ADDITIONAL EQUATIONS-STATION 3

-0.36528959E 07	0.62558795E 07	-0.53186800E 07	0 19863600E 07	-0 13439300E 07	0 12588200E 06
-0 19400759E 05	0 33549300E 04	0 47685000E 04	-0 88208000E 00	0 16601600E-01	0 92968798E 01
-0.84375000E 01	0.38124959E 01	-0.12500000E 01	-0 31250000E-00		
0.	0.	0.	0	0	0
0	0	0	0	0	0
0.	0.	0.	0.		
0.	0.	0	0	0	0
0	0	0	0	0	0
0.	0.	0	0		
0.	0.	0	0	0	0
0	0	0	0	0	0
0.	0.	0	0		

SOLUTION OF N SECOND-ORDER SIMULTANEOUS DIFFERENTIAL EQUATIONS WITH TIME DEPENDENT INPUTS

COEFFICIENT OF ADDITIONAL EQUATIONS-STATION 4

0 95∠8∠700E C6	-0 404755S9E 07	0 467556S9E 07	-0 42841499E 07	0 28985500E 07	-0 27149700E 06
0 418445C0E 05	-0 723635C0E 04	0 56580900E 04	0 81140099E 00	0 19433600E-00	0 46640600E 01
-0 3553750OE 01	0 568749S9E C1	-0 512500C0E 01	0 19374999E 01		
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0		
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0		
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0		

COEFFICIENT OF ADDITIONAL EQUATIONS-STATION 5

0 55∠827C0E 06	-0 404755S9E 07	0 467556S9E 07	-0 42841499E 07	0 28985500E 07	-0 27149700E 06
0 418445C0E C5	-0 72363500E C4	0 56580900E 04	0 81140099E 00	0 19433600E-00	0 46640600E 01
-0 3553750OE 01	0 56874999E 01	-0 51250000E 01	0 19374999E 01		
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0		
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0		
0.	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0		

COEFFICIENT OF ADDITIONAL EQUATIONS-STATION 6

-0 41584859E 06	0 16953100E C7	-0 339135C0E 07	0 11199500E 08	-0 98918200E 07	0 92652800E 06
-0 14∠799C0E 06	0 246963S9E 05	-0 15336599E 04	-0 24320100E 01	0 24299300E 01	-0 10707000E 02
0 ∠38672C0E 0∠	-0 202811S9E C2	0 131249S9E 02	-0 54843700E 01		
0	0	0	0	0	0
0	0	0	0	0	0
0.	0	0	0		
0.	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0		
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0		

COEFFICIENT OF ADDITIONAL EQUATIONS-STATION 7

0 804S61S9E 05	-0 32815300E 06	0 656427S9E 06	-0 16556900E 08	0 24155500E 08	-0 92256500E 07
0 14218700E 07	-0 24590699E 06	0 45006800E 05	0 39144300E 01	-0 29858400E-00	0 22183599E 02
-0.307S69C0E 02	0 313593S9E C2	-0 17734399E 02	0 43906299E 01		
0	0	0	0	0	0
0	0	0	0	0	0
0.	0	0	0		
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0		
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0		

COEFFICIENT OF ADDITIONAL EQUATIONS-STATION 8

0 804S61S9E 05	-0.32815300E 06	0 656427S9E 06	-0 16556900E 08	0 24155500E 08	-0 92256500E 07
0 14218700E 07	-0 24590699E 06	0 45006800E 05	0 39144300E 01	-0 29858400E-00	0 22183599E 02
-0 307S69C0E 02	0 313593S9E 02	-0 17734399E 02	0 43906299E 01		
0.	0.	0.	0.	0.	0
0	0	0	0	0	0
0.	0.	0.	0.		
0.	0.	0.	0.	0.	0
0	0	0	0	0	0
0.	0.	0.	0.		
0.	0.	0.	0.	0.	0
0	0	0	0	0	0
0.	0.	0.	0.		

SOLUTION OF N SECOND-ORDER SIMULTANEOUS DIFFERENTIAL EQUATIONS WITH TIME DEPENDENT INPUTS

COEFFICIENT OF ADDITIONAL EQUATIONS-STATION 9

-0.176252SSE 05	0.718453S9E 05	-0.143714S9E 06	0.36247899E 07	-0 93865100E 07	0 95895500E 07
-0 43625800E 07	0 7545760CE 06	-0 127400S9E 06	0 77847300E 00	-0 39182100E 01	0 33468699E 02
-0.385000C0E 02	0.144844C0E 02	-0.347656C0E 01	0 40390600E 01		
0.	0.	0.	0	0	0
0	0	0	0	0	0
0.	0.	0.	0		
0.	0.	0.	0.	0	0
0	0	0	0	0	0
0.	0.	0.	0		
0.	0.	0.	0.	0	0
0	0	0	0	0	0
0.	0.	0	0		

COEFFICIENT OF ADDITIONAL EQUATIONS-STATION 10

0.35E495C0E 04	-0 16257000E C5	0 32527199E 05	-0 82041799E 06	0 21244900E 07	-0 41921099E 07
0.483S3900E 07	-0 23817699E 07	0 4122C400E 06	-0 35329899E 01	0 97548499E 01	-0 66200199E 02
0.5038E695E 02	-0 403086C0E 02	0 92105359E 01	-0 64765599E 01		
0.	0	0	0	0	0
0	0	0	0	0	0
0.	0	0	0		
0	0	0	0	0	0
0.	0	0	0	0	0
0	0	0	0		
0	0.	0	0	0	0
0	0	0	0	0	0
0	0	0	0		

COEFFICIENT OF ADDITIONAL EQUATIONS-STATION 11

-0 10C38000E 04	0 41129395E C4	-0 82446159E 04	0 20798299E 06	-0 53859799E 06	0 10627799E 07
-0 24080459E 07	0 29998799E 07	-0 13178799E 07	0 23321199E 01	-0 58642900E 01	0 52597199E 02
-0.675462C5E 02	0 37537095E 02	-0 91367199E 01	0 63281299E 01		
0	0	0	0	0	0
0	0	0	0	0	0
0.	0	0	0		
0	0	0	0	0	0
0.	0	0	0	0	0
0.	0	0	0		
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0		

COEFFICIENT OF ADDITIONAL EQUATIONS-STATION 12

0 10332200E 07	0 64554995E-01	-0 18731300E-00	0 11664700E 01	-0 16595500E 01	0 19525699E-00
0 425325C0E-00	-0 21624900E-00	0 45719899E 03	-0 14635500E 07	0 48704400E 06	-0 14766999E 06
C 5EC649S5E C5	-0 81535495E 04	0 12625000E 04	-0 21829700E 03		
0	0	0	0	0	0
0.	0	0	0	0	0
0	0	0	0		
0	C	0	0	0	0
0	0	0	0	0	0
0	0	0	0		
0.	0	0	0	0	0
0.	0	0	0	0	0
0.	0	0	0		

COEFFICIENT OF ADDITIONAL EQUATIONS-STATION 13

-0 733106S5E 06	0 27954300E-C0	0 28867400E-01	-0 16455100E 01	0 12624100E 01	-0 33959600E-00
-0 1025690CE-00	0 13297900E-00	0 939851995 03	0 15937600E 07	-0 97408800E 06	0 29534100E 06
-0.196125S5E C6	0 16387395E C5	-0 25255200E 04	0 43654700E 03		
0	0	0	0	0	0
0	0	0	0	0	0
0.	0	0	0		
0	0	0	0	0	0
0.	0	0	0	0	0
0.	0	0	0		
0.	0	0	0	0	0
0	0	0	0	0	0
0.	0	0	0		

SOLUTION OF N SECOND-ORDER SIMULTANEOUS DIFFERENTIAL EQUATIONS WITH TIME DEPENDENT INPUTS

COEFFICIENT OF ADDITIONAL EQUATIONS-STATION 14

0 14592600E 06	-0 26871300E-00	-0 44743259E-00	0 89409000E 00	-0 15199700E 01	-0.88163099E 00
0 10743059E 01	-0 66346395E 00	0 12747999E 04	-0 90875800E 06	0 12344600E 07	-0 12383500E 07
0 82c371C0E C6	-0 68712095E 05	0 10589299E 05	-0 18307500E 04		
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0		
0	0	0	0	0	0
0	0	0	0	0	0
0.	0.	0.	0.		
0.	0.	0.	0.	0.	0.
0	0	0	0	0	0
0.	0.	0.	0.		

COEFFICIENT OF ADDITIONAL EQUATIONS-STATION 15

-0.626500S9E 05	0.19660600E C1	-0.35851599E-00	0.15835900E-00	-0 23936000E 01	0 35292900E 01
-0 33268400E 01	0 22490799E 01	-0 76480499E 02	0 37973300E 06	-0.87278200E 06	0 28167500E 07
-0.24378455E 07	0.20369295E 06	-0.31392600E 05	0.54276700E 04		
0.	0.	0.	0.	0.	0
0	0	0	0	0	0
0.	0.	0.	0.		
0.	0.	0.	0.	0	0
0	0	0	0	0	0
0.	0.	0.	0.		
0.	0.	0.	0	0	0
0	0	0	0	0	0
0.	0.	0.	0.		

COEFFICIENT OF ADDITIONAL EQUATIONS-STATION 16

0.104827S9E 05	-0.4524189SE C1	-0.50827000E 00	0.47208500E 01	-0 56857699E 01	-0 49278499E 01
0 540623S9E 01	-0 44926199E 01	0 98946100E 04	-0 63514699E 05	0 14598399E 06	-0 35761899E 07
0.52C7146CE C7	-0.15861895E C7	0.30611400E 06	-0 52938800E 05		
0.	0.	0	0	0	0
0	0	0	0	0	0
0.	0.	0	0		
0.	0	0	0	0	0
0	0	0	0	0	0
0.	0	0	0		
0.	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0		

INITIAL CONDITIONS FOR ADDITIONAL EQUATIONS (CONSTANT)

STATION 1

0	0	0	0

STATION 2

0	0	0	0

STATION 3

0	0	0	0

STATION 4

0	0	0	0

STATION 5

0	0	0	0

STATION 6

0	0	0	0

STATION 7

0	0	0	0

SOLUTION OF A SECOND-ORDER SIMULTANEOUS DIFFERENTIAL EQUATIONS WITH TIME DEPENDENT INPUTS

STATION 8

0 0 0 0

STATION 9

0 0 0 0

STATION 10

0 0 0 0

STATION 11

0 0 0 0

STATION 12

0 0 0 0

STATION 13

0 0 0 0

STATION 14

0 0 0 0

STATION 15

0 0 0 0

STATION 16

0 0 0 0

F MATRIX COEFFICIENT IDENTIFICATION

LOC. 036671 THRU 036671 ISX FROM 030513

036672036672

F MATRIX COEFFICIENTS

0.37603015E 03

SOLUTION OF A SECOND-ORDER SIMULTANEOUS DIFFERENTIAL EQUATIONS WITH TIME DEPENDENT INPUTS

TASK 3.8 C.K 30000.E-55 ALLM. INITIAL COND. 0.0 0000000000000000000000000000000000000000000000000000000000000000

(T)I = 0. (T)F = 0.18000000E-00 (T)R = 0.09999999E 01

(DELTA T)O = 0.55555555E-05 (DELTA T)MIN = 0.99999999E-07 (DELTA T)MAX = 0.99999999E-03

OUTPUT FROM EQUATIONS OF MOTION

T = 0.16655587E-00

0.14280438E 03 -0.12462624E-00 0.16319402E-00 -0 47404358E 03 -0 80191956E-01 0 16769436E-00

-0.32557152E 04 0.15101206E-00 0.18784934E-00 -0 11451347E 05 0 86538161E 00 0 24665613E-00

-0.17660215E 05 0.98468557E 00 0.25617386E-00 -0 14656235E 05 0 11674184E 01 0 27007481E-00

-0.14674566E 05 0.11523940E 01 0.27132962E-00 -0 93741044E 04 0 75918145E 00 0 23584393E-00

0.58067101E 02 -0.31670637E-01 0.17047175E-00 -0 20046604E 04 0 55156797E-01 0 17858255E-00

-0.51455623E 04 0.32213810E-00 0.20116007E-00 -0 11468618E 05 0 87340586E 00 0 24686901E-00

-0.17595260E 05 0.97.65638E 00 0.25483851E-00 -0 14222252E 05 0 11279655E 01 0 26717369E-00

-0.14031667E 05 0.11368024E 01 0.26686019E-00 -0 85605815E 04 0 69001991E 00 0 22984648E-00

SOLUTION OF N SECOND-ORDER SIMULTANEOUS DIFFERENTIAL EQUATIONS WITH TIME DEPENDENT INPUTS

OUTPUT FROM ADDITIONAL EQUATIONS

I = 0.16655587E-00

1	-0.62161451E 04	0.	0	0
2	-0 32321947E 04	0	0.	0
3	-0.40627962E 05	0	0	0
4	-0 15242875E 05	0	0	0
5	-0.15242875E 05	0	0	0.
6	0 24816836E 05	0	0	0
7	0.29421424E 05	0	0	0
8	0 29421424E 05	0	0	0
9	0 34009521E 05	0	0	0
10	0 35335735E 05	0	0	0
11	0 28803663E 05	0	0	0
12	-0 80642082E 04	0	0	0.
13	-0 40748059E 04	0	0	0
14	-0 13714315E 04	0	0	0
15	0 34086861E 04	0	0	0
16	0 44144513E 04	0	0	0

STRESS AT STATION 35

σ = 35340 psi

t = 0.167 sec.

AT 0 16712815E-00 DELTA T EQUALS 0 99999999E-05

AT 0 16712815E-00 DELTA T EQUALS 0 49999999E-05

AT 0 16761313E-00 DELTA T EQUALS 0 99999999E-05

AT 0 16761313E-00 DELTA T EQUALS 0 49999999E-05

AT 0 16773811E-00 DELTA T EQUALS 0 99999999E-05

AT 0 16773811E-00 DELTA T EQUALS 0 49999999E-05

AT 0 16785809E-00 DELTA T EQUALS 0 24999999E-05

AT 0 16792059E-00 DELTA T EQUALS 0 49999999E-05

APPENDIX E

HEAT TRANSFER AND PRESSURE DROP CODE FOR FUEL ASSEMBLY OF CONCENTRIC RING STAGES

```
START TIME 11.864 DATE 08/12/65 ID CARD $JOB   CHECK11 KN250    02-121  4209-038-21691        TRUSHIN        9357  1
          $EXECUTE      IBJOB
IBJOB VERSION  4
$IBJOB        GO,MAP,FIOCS
$IBJOB        GO,MAP,FIOCS
$ BLDR K250                                                    K2500000
$IBLDR STAGE                                                   STAG0000
$IBLDR PDROP                                                   PDRO0000
$IBLDR ADJUST                                                  ADJU0000
$IBLDR STATM                                                   STAT0000
$IBLDR HEAT                                                    HEAT0000
$IBLDR SHUFFL                                                  SHUF0000
$IBLDR PRPTY                                                   PRPT0000
$IBLDR COEFK                                                   COFF0000
$IBLDR COEFN                                                   COEF0000
$IBLDR CSUBP                                                   CSUB0000
$IBLDR GAMMA                                                   GAMM0000
$IBLDR VISCO                                                   VISC0000
$IBLDR FRFCTR                                                  FRFC0000
$IBLDR BNDRY                                                   BNDR0000
$IBLDR ODUMP                                                   ODUM0000
$DATA
```

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MEMORY MAP

SYSTEM	00000 THRU 02717
FILE BLOCK ORIGIN	02720

NUMBER OF FILES - 2

1. UNIT05
2. UNIT06

FILE LIST ORIGIN	02750
PRE-EXECUTION INITIALIZATION	02754
CALL ON OBJECT PROGRAM	02777
OBJECT PROGRAM	03004 THRU 60631

1.	DECK	'K250 '	*	03004
2.	DECK	'STAGE '	*	06446
3.	DECK	'PDROP '	*	15700
4.	DECK	'ADJUST'	*	21041
5.	DECK	'STATM '	*	24313
6.	DECK	'HEAT '	*	27400
7	DECK	'SHUFFL'	*	32625
8.	DECK	'PRPTY '	*	37203
9.	DECK	'COEFK '	*	42416
10.	DECK	'COEFN '	*	42447
11.	DECK	'CSUBP '	*	42500
12.	DECK	'GAMMA '	*	42531
13.	DECK	'VISCO '	*	42562
14.	DECK	'FRFCTR'	*	42613
15.	DECK	'BNDRY '	*	42717
16.	DECK	'DDUMP '	*	45653
17.	SUBR	'.IBSYS'		00000
18.	SUBR	'.IOEX '		00702
19.	SUBR	'.JBCON'		02652
20.	SUBR	'.LXCON'		45715
21.	SUBR	' IODEF'		46371
22.	SUBR	' IOCSF'		46610
23.	SUBR	'.LXSL '		51103
24.	SUBR	'.FPTRP'		51242
25.	SUBR	'.ERAS.'		51452
26.	SUBR	'XIT '		51456
27.	SUBR	'FXE1 '		51457
28.	SUBR	'FOUT '		52031
29.	SUBR	'FCNV '	*	52373
30.	SUBR	'FIOS '		55064
31.	SUBR	'FIOH '		55312
32.	SUBR	'FSFL '		56353
33.	SUBR	'FWRD '		56573
34.	SUBR	'FRDD '		56622
35.	SUBR	'UN05 '		56654
36.	SUBR	'UN06 '		56655

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37.	SUBR	*FLOG *	56661
38.	SUBR	*FXPF *	57022
39.	SUBR	*FSQR *	57142
40.	SUBR	*FXP3 *	57247
41.	SUBR	*FDMP *	57374
42.	SUBR	*77 *	76664

(* = INSERTIONS OR DELETIONS MADE IN THIS DECK)

INPUT - OUTPUT BUFFERS 60632 THRU 76515

UNUSED CORE 76516 THRU 76663

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PROPELLANT IS HYDROGEN
EXIT TEMP. = 4460.DEG R INLET TEMP. = 322.DEG R WT. FLOW = 0.95660 LBS/SEC

TOTAL POWER = 15189.78TU/SEC INLET PRESSURE = 105120. PSF NO. OF STAGES = 26
AXIAL POWER DISTRIBUTION PER STAGE/
0.573E-01
0.642E-01
0.692E-01
0.709E-01
0.696E-01
0.671E-01
0.636E-01
0.594E-01
0.549E-01
0.504E-01
0.461E-01
0.420E-01
0.378E-01
0.340E-01
0.308E-01
0.275E-01
0.247E-01
0.220E-01
0.196E-01
0.177E-01
0.158E-01
0.140E-01
0.123E-01
0.109E-01
0.970E-02
0.850E-02

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INPUT DATA. STAGE NO. 1
STAGE POWER= 870.4 BTU/SEC
NUMBER OF RINGS=10
NUMBER OF SHIELDS= 1
STAGE LENGTH= 0.1250 FT.
ENTRANCE PRESSURE= 105120.0 PSF
HEAT LOSS= =0.0288 BTU/SEC

PASSAGE RADII,FT INNER	OUTER	F AREA,SQIN	S AREA,SQIN	RNG PWR DIST	EFF DIAM,IN	PWR DENSITY BTU/SEC-SQIN	EMISSIVITY
0.01642	0.01983	0.055921	1.857057	0.00060	0.0818	0.2812	0.2300
0.02158	0.02683	0.114976	4.683357	0.04000	0.1260	7.4337	0.2600
0.02858	0.03383	0.148226	6.266718	0.05320	0.1260	7.3888	0.2600
0.03558	0.04083	0.181477	7.850079	0.06640	0.1260	7.3620	0.2600
0.04258	0.04783	0.214728	9.433441	0.07960	0.1260	7.3442	0.2600
0.04958	0.05483	0.247978	11.016802	0.09280	0.1260	7.3316	0.2600
0.05658	0.06183	0.281229	12.600163	0.10604	0.1260	7.3248	0.2600
0.06358	0.06883	0.314479	14.183525	0.11925	0.1260	7.3178	0.2600
0.07058	0.07583	0.347730	15.766886	0.13250	0.1260	7.3143	0.2600
0.07758	0.08233	0.343622	17.350247	0.14567	0.1140	7.3075	0.2600
0.08408	0.08792	0.298794	18.820511	0.15794	0.0922	7.3041	0.2600
0.08917	0.09917		9.943509	0.00600		0.5252	0.2300
							0.0500

PLATE TEMPERATURES FOR ALL INCREMENTS. DEGREES R

INCREMENT NO.	1	2	3	4	5	6	7	8	9	10
1	377.7	437.4	477.9	509.5	537.4	566.0	588.7	611.5	635.7	557.5
2	2594.3	3805.5	4160.4	4312.8	4392.8	4462.6	4472.2	4475.5	4498.8	4474.3
3	2455.3	3800.4	4220.9	4403.3	4499.5	4554.6	4584.0	4600.3	4653.0	4619.8
4	2444.3	3784.6	4206.3	4389.9	4486.7	4541.0	4571.4	4588.3	4642.6	4608.7
5	2434.5	3768.8	4189.1	4372.3	4469.0	4523.2	4553.9	4570.9	4625.5	4591.8
6	2427.3	3757.1	4176.2	4359.0	4455.6	4509.8	4540.5	4557.7	4612.5	4579.1
7	2423.0	3750.1	4168.4	4351.0	4447.4	4501.7	4532.4	4549.6	4604.6	4571.3
8	2418.4	3742.9	4160.7	4343.0	4439.4	4493.6	4524.4	4541.7	4596.6	4563.5
9	2419.1	3744.9	4162.5	4344.4	4440.5	4494.4	4525.1	4542.0	4595.6	4562.7
10	2507.5	3821.7	4220.4	4390.4	4479.7	4528.6	4556.7	4568.4	4605.4	4573.2
11	2474.9	3611.7	3947.7	4094.9	4174.0	4219.8	4267.9	4269.3	4278.5	4262.1
12	414.4	480.1	516.4	542.9	565.3	585.4	606.8	623.1	640.0	656.0
13	683.3	683.9	684.5	685.1	685.7	686.3	686.9	687.5	688.1	688.7
AV FUEL TEMP	2440.5	3724.4	4121.8	4294.3	4385.4	4437.5	4469.1	4481.9	4524.6	4494.3
AV GAS TEMP	322.0	345.0	368.3	391.9	415.8	440.0	464.5	489.2	514.3	539.5
DIFF IN TEMP	2118.5	3379.4	3753.5	3902.4	3969.6	3997.5	4004.6	3992.6	4010.3	3954.8

STAGE AVERAGE FUEL TEMP = 4137.4 DEG R
STAGE AVERAGE OUTLET GAS TEMP = 565.0 DEG R
STAGE AVERAGE OUTLET DYNAMIC HEAD = 1.3005 PSI

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COMPUTED TEMPERATURES AND PRESSURES, STAGE NO. 1

	PLATE TEMPERATURES			GAS TEMPERATURES		
	ENTRANCE	CENTER	EXIT	ENTRANCE	CENTER	EXIT
CENTER PLUG	378.	537.	658.	322.	430.	546.
FUEL RINGS	2594.	4393.	4474.	322.	445.	574.
	2455.	4500	4620.	322.	445.	575.
	2444.	4487.	4609.	322.	444.	574.
	2435.	4469.	4592.	322.	444.	573.
	2427.	4455.	4579.	322.	443.	572.
	2423.	4447.	4571.	322.	443.	572.
	2418.	4439.	4564.	322.	443.	572.
	2419.	4440.	4563.	322.	444.	573.
	2507	4480.	4573.	322.	457.	600.
	2475.	4174.	4262.	322.	404.	490.
RADTN SHIELDS	414.	565.	656.			
CONTAINMNT SHELL	683.	686.	689.			

PASSAGE PRESSURE DROPS, PSF			MASS FLOW RATE			
FRICTION	MOMENTUM	TOTAL	LB/SEC-FT**2	PASSAGE WT FLOW, LB/SEC	EXIT MACH NO.	EXIT DYNAMIC HEAD, PSI
27.5	146.4	173.9	53 584	0.02081	0.0495	1.2358
13.3	163.8	177.2	53.539	0.04276	0.0506	1.2954
13.3	164.0	177.3	53.462	0.05505	0.0506	1.2938
13.3	163.9	177.2	53.534	0.06748	0.0506	1.2954
13.3	163.7	177.1	53.601	0.07994	0.0507	1.2967
13.4	163.7	177.0	53.647	0.09240	0.0507	1.2976
13.4	163.6	177.0	53.682	0.10486	0.0507	1.2983
13.4	163.8	177.2	53.735	0.11730	0.0507	1.3004
13.4	164.0	177.4	53.617	0.12937	0.0507	1.2981
14.7	165.6	180.3	51.177	0.12211	0.0495	1.2388
26.8	137.4	164.2	59.974	0.12452	0.0526	1.3885

STAGE END PRESSURE DROPS, PSF					TOTAL	REYNOLDS NUMBERS		
CONTRACTION		ENLARGEMENT			PRESSURE	ENTRANCE	CENTER	EXIT
FRICTION	MOMENTUM	FRICTION	MOMENTUM	TOTAL	DROP, PSF			
21.3	49.0	10.7	-76.4	4.5	178.4	87575.	73595.	62241.
21.2	48.9	11.2	-80.1	1.2	178.4	134718.	110971.	92648.
21.2	48.8	11.2	-80.0	1.1	178.4	134523.	110840.	92432.
21.2	48.9	11.2	-80.1	1.2	178.4	134705.	111091.	92652.
21.3	49.1	11.2	-80.2	1.3	178.4	134874.	111284.	92857.
21.3	49.1	11.2	-80.2	1.4	178.4	134990.	111417.	92999.
21.3	49.2	11.2	-80.3	1.5	178.4	135078.	111518.	93107.
21.4	49.3	11.2	-80.4	1.5	178.6	135211.	111642.	93223.
21.3	49.1	11.2	-80.3	1.3	178.7	134912.	111232.	92840.
19.4	44.7	10.7	-76.6	-1.8	178.5	116510.	94619.	77744.
26.6	61.4	12.0	-85.9	14.2	178.3	110379.	96193.	84064.

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INPUT DATA. STAGE NO. 2
STAGE POWER= 975.2 BTU/SEC
NUMBER OF RINGS=10
NUMBER OF SHIELDS= 1
STAGE LENGTH= 0.1250 FT.
ENTRANCE PRESSURE= 104941.5 PSF
HEAT LOSS= 0.0177 BTU/SEC

PASSAGE RADII,FT INNER	OUTER	F AREA,SQIN	S AREA,SQIN	RNG PWR DIST	EFF	DIAM,IN	PWR DENSITY BTU/SEC SQIN	EMISSIVITY
0.01642	0.01983	0.055921	1.857057	0.00060		0.0818	0.3151	0.2300
0.02158	0.02683	0.114976	4.583357	0.04000		0.1260	8.3289	0.2600
0.02858	0.03383	0.148226	6.266718	0.05320		0.1260	8.2786	0.2600
0.03558	0.04083	0.181477	7.850079	0.06640		0.1260	8.2486	0.2600
0.04258	0.04783	0.214728	9.433441	0.07960		0.1260	8.2286	0.2600
0.04958	0.05483	0.247978	11.016802	0.09280		0.1260	8.2144	0.2600
0.05658	0.06183	0.281229	12.600163	0.10604		0.1260	8.2069	0.2600
0.06358	0.06883	0.314479	14.183525	0.11925		0.1260	8.1990	0.2600
0.07058	0.07583	0.347730	15.766886	0.13250		0.1260	8.1951	0.2600
0.07758	0.08233	0.343622	17.350247	0.14567		0.1140	8.1875	0.2600
0.08408	0.08792	0.298794	18.820511	0.15794		0.0922	8.1836	0.2600
0.08917	0.09917		9.943309	0.09600			0.5884	0.2300
								0.0500

PLATE TEMPERATURES FOR ALL INCREMENTS, DEGREES R

INCREMENT NO. M	1	2	3	4	5	6	7	8	9	10
1	608.5	675.6	721.8	758.5	791.2	824.1	851.0	877.9	903.8	931.5
2	2747.4	3899.9	4247.6	4399.3	4477.5	4543.1	4551.9	4554.9	4575.2	4550.7
3	2597.9	3855.0	4255.3	4435.2	4528.5	4582.7	4612.8	4629.9	4678.2	4641.5
4	2588.7	3840.7	4241.2	4421.9	4515.8	4569.4	4600.5	4618.2	4668.1	4630.7
5	2580.1	3827.8	4227.2	4407.5	4501.2	4554.7	4585.9	4603.7	4654.4	4617.3
6	2574.9	3820.0	4218.5	4398.5	4492.1	4545.5	4576.7	4594.6	4645.9	4609.0
7	2568.0	3809.5	4206.9	4386.6	4480.1	4533.4	4564.7	4582.7	4634.6	4597.9
8	2562.9	3801.7	4198.4	4377.8	4471.3	4524.6	4555.9	4573.9	4626.1	4589.5
9	2566.0	3806.6	4203.5	4382.7	4476.0	4529.2	4560.4	4577.8	4628.1	4591.8
10	2657.8	3881.1	4261.8	4431.0	4519.3	4568.9	4597.7	4605.0	4536.5	4602.9
11	2626.8	3707.3	4035.7	4185.9	4269.1	4319.5	4366.7	4361.5	4365.0	4346.0
12	590.7	661.5	701.4	731.4	757.2	780.6	804.7	823.1	842.0	860.1
13	689.2	689.7	690.2	690.7	691.2	691.7	692.2	692.7	693.2	693.7
AV FUEL TEMP	2583.7	3787.2	4166.8	4337.7	4427.2	4479.3	4511.1	4522.6	4561.1	4528.0
AV GAS TEMP	565.0	593.6	622.5	651.5	680.5	709.7	739.0	768.2	797.5	826.8
DIFF IN TEMP	2018.8	3193.5	3544.3	3686.2	3746.6	3769.5	3772.1	3754.3	3763.7	3701.2

STAGE AVERAGE FUEL TEMP = 4190.5 DEG R
STAGE AVERAGE OUTLET GAS TEMP = 856.1 DEG R
STAGE AVERAGE OUTLET DYNAMIC HEAD = 1.9727 PSI

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COMPUTED TEMPERATURES AND PRESSURES. STAGE NO. 2

	PLATE TEMPERATURES			GAS TEMPERATURES		
	ENTRANCE	CENTER	EXIT	ENTRANCE	CENTER	EXIT
CENTER PLUG	609.	791.	931.	546.	679.	818.
FUEL RINGS	2747.	4477.	4551.	573.	725.	876.
	2598.	4529.	4641.	575.	725.	877.
	2589.	4516.	4631.	574.	724.	875.
	2580.	4501.	4617.	573.	723.	874.
	2575.	4492.	4609.	572.	722.	872.
	2568.	4480.	4598.	572.	721.	871.
	2563.	4471.	4590.	572.	720.	871.
	2566.	4476.	4592.	573.	724.	874.
	2658.	4519.	4603.	600.	769.	939.
	2627.	4269.	4346.	492.	589.	689.
RADTN SHIELDS	591.	757.	860.			
CONTAINMNT SHELL	689.	691.	694.			

PASSAGE PRESSURE DROPS.PSF			MASS FLOW RATE			
FRICTION	MOMENTUM	TOTAL	LB/SEC-FT**2	PASSAGE WT FLOW.LB/SEC	EXIT MACH NO.	EXIT DYNAMIC HEAD.PSI
54.5	171.4	225.9	52.635	0.02044	0.0593	1.7888
29.9	198.2	228.1	53.592	0.04271	0.0625	1.9874
29.8	197.3	227.2	53.459	0.05501	0.0624	1.9805
29.8	197.2	227.0	53.534	0.06754	0.0625	1.9818
29.8	197.0	226.8	53.587	0.07999	0.0625	1.9818
29.8	196.5	226.3	53.580	0.09245	0.0624	1.9782
30.0	197.6	227.6	53.826	0.10492	0.0626	1.9932
29.9	196.9	226.8	53.730	0.11731	0.0625	1.9855
29.9	197.6	227.5	53.617	0.12946	0.0625	1.9857
33.6	196.6	230.2	50.478	0.12045	0.0610	1.8893
49.7	167.0	216.7	60.874	0.12631	0.0631	2.0168

STAGE END PRESSURE DROPS. PSF					TOTAL	REYNOLDS NUMBERS		
CONTRACTION		ENLARGEMENT			PRESSURE	ENTRANCE	CENTER	EXIT
FRICTION	MOMENTUM	FRICTION	MOMENTUM	TOTAL	DROP.PSF			
31.5	73.7	15.4	-110.5	10.0	235.9	59247.	52566.	46258.
34.3	80.2	17.1	-122.9	8.7	236.8	89731.	79051.	69291.
34.2	79.9	17.1	-122.5	8.7	235.9	89373.	78831.	69059.
34.2	80.0	17.1	-122.5	8.8	235.8	89596.	79041.	69256.
34.2	80.1	17.1	-122.5	8.9	235.7	89778.	79209.	69414.
34.2	80.0	17.1	-122.3	8.9	235.2	89831.	79264.	69471.
34.5	80.7	17.2	-123.2	9.1	236.7	90293.	79691.	69863.
34.3	80.3	17.1	-122.8	9.0	235.8	90158.	79568.	69753.
34.3	80.2	17.1	-122.8	8.8	236.3	89797.	79181.	69405.
31.8	74.5	16.3	-116.8	5.8	236.0	73973.	64890.	56431.
37.9	88.7	17.4	-124.7	19.2	236.0	83058.	74931.	67314.

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INPUT DATA. STAGE NO. 3
STAGE POWER= 1051.1 BTU/SEC
NUMBER OF RINGS=10
NUMBER OF SHIELDS= 1
STAGE LENGTH= 0.1250 FT.
ENTRANCE PRESSURE= 104705.5 PSF
HEAT LOSS= 0.0795 BTU/SEC

PASSAGE RADII,FT INNER	OUTER	F AREA,SQIN	S AREA,SQIN	RNG PWR DIST	EFF DIAM,IN	PWR DENSITY BTU/SEC SQIN	EMISSIVITY
0.01642	0.01983	0.055921	1.857057	0.00060	0.0818	0.3396	0.2300
0.02158	0.02683	0.114976	4.683357	0.04000	0.1260	8.9776	0.2600
0.02858	0.03383	0.148226	6.266718	0.05320	0.1260	8.9233	0.2600
0.03558	0.04083	0.181477	7.850079	0.06640	0.1260	8.8910	0.2600
0.04258	0.04783	0.214728	9.433441	0.07960	0.1260	8.8695	0.2600
0.04958	0.05483	0.247978	11.016802	0.09280	0.1260	8.8542	0.2600
0.05658	0.06183	0.281229	12.600163	0.10604	0.1260	8.8460	0.2600
0.06358	0.06883	0.314479	14.183525	0.11925	0.1260	8.8375	0.2600
0.07058	0.07583	0.347730	15.766886	0.13250	0.1260	8.8334	0.2600
0.07758	0.08233	0.343622	17.350247	0.14567	0.1140	8.8251	0.2600
0.08408	0.08792	0.298794	18.820511	0.15794	0.0922	8.8210	0.2600
0.08917	0.09917		9.943509	0.00600		0.6343	0.2300
							0.0500

PLATE TEMPERATURES FOR ALL INCREMENTS. DEGREES R

INCREMENT NO. M	1	2	3	4	5	6	7	8	9	10
1	882.6	950.7	997.5	1036.5	1073.0	1109.6	1140.6	1170.8	1201.9	1231.3
2	2877.5	3908.8	4232.2	4387.0	4483.3	4562.5	4589.0	4604.5	4636.3	4630.4
3	2724.7	3830.1	4210.4	4399.9	4510.6	4575.2	4617.5	4646.5	4707.4	4697.0
4	2712.9	3810.9	4190.4	4380.1	4491.5	4555.5	4598.4	4628.1	4690.1	4679.7
5	2704.4	3797.2	4175.2	4364.3	4476.2	4540.1	4583.0	4613.0	4675.0	4664.7
6	2698.5	3787.7	4164.8	4353.4	4465.7	4529.6	4572.5	4602.7	4664.6	4654.4
7	2695.5	3782.9	4159.5	4347.9	4460.7	4524.4	4567.3	4597.6	4659.5	4649.4
8	2692.5	3778.3	4154.5	4342.7	4455.7	4519.4	4562.3	4592.5	4654.5	4644.4
9	2695.2	3783.6	4160.3	4348.4	4460.2	4523.8	4566.6	4596.5	4657.9	4648.0
10	2790.4	3875.4	4238.9	4414.0	4515.3	4574.9	4614.6	4640.9	4692.1	4685.8
11	2766.4	3758.5	4070.8	4218.0	4302.9	4356.3	4404.1	4411.6	4428.5	4423.4
12	791.8	864.5	905.7	937.3	964.7	989.9	1015.4	1035.9	1056.9	1077.2
13	694.2	694.7	695.2	695.7	696.2	696.7	697.2	697.7	698.2	698.7
AV FUEL TEMP	2708.5	3773.1	4133.2	4310.3	4414.8	4476.2	4518.0	4542.6	4593.7	4584.7
AV GAS TEMP	856.1	887.6	919.7	950.8	982.4	1014.0	1045.6	1077.2	1108.8	1140.4
DIFF IN TEMP	1852.4	2885.5	3214.0	3359.5	3432.4	3462.1	3472.3	3465.4	3484.9	3444.4

STAGE AVERAGE FUEL TEMP = 4205.5 DEG R
STAGE AVERAGE OUTLET GAS TEMP = 1171.9 DEG R
STAGE AVERAGE OUTLET DYNAMIC HEAD = 2.7064 PSI

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COMPUTED TEMPERATURES AND PRESSURES. STAGE NO. 3

	PLATE TEMPERATURES			GAS TEMPERATURES		
	ENTRANCE	CENTER	EXIT	ENTRANCE	CENTER	EXIT
CENTER PLUG	883.	1073.	1231.	818.	965.	1116.
FUEL RINGS	2878.	4483.	4630.	875.	1041.	1204.
	2725.	4511.	4697.	877.	1041.	1205.
	2713.	4491.	4680.	875.	1039.	1202.
	2704.	4476.	4665.	874.	1036.	1199.
	2699.	4466.	4654.	872.	1035.	1197.
	2696.	4461.	4649.	871.	1033.	1195.
	2693.	4456.	4644.	871.	1033.	1194.
	2695.	4460.	4648.	875.	1039.	1202.
	2790.	4515.	4686.	938.	1121.	1305.
	2766.	4303.	4423.	689.	797.	907.
RADTN SHIELDS	792.	965.	1077.			
CONTAINMNT SHELL	694.	696.	699.			

PASSAGE PRESSURE DROPS, PSF			MASS FLOW RATE			
FRICTION	MOMENTUM	TOTAL	LB/SEC-FT**2	PASSAGE WT FLOW, LB/SEC	EXIT MACH NO.	EXIT DYNAMIC HEAD, PSI
90.5	182.9	273.4	51.650	0.02006	0.0683	2.3598
54.1	216.1	270.2	53.524	0.04276	0.0736	2.7346
54.4	215.7	270.1	53.585	0.05515	0.0737	2.7420
54.5	215.6	270.0	53.688	0.06765	0.0737	2.7448
54.5	215.5	270.0	53.771	0.08016	0.0737	2.7468
54.5	215.4	269.8	53.813	0.09267	0.0737	2.7465
54.4	215.2	269.6	53.830	0.10515	0.0737	2.7438
54.4	215.4	269.9	53.867	0.11763	0.0737	2.7469
54.3	215.8	270.1	53.628	0.12953	0.0736	2.7399
61.7	211.9	273.6	50.217	0.11982	0.0719	2.6070
79.1	184.6	263.7	60.742	0.12603	0.0724	2.6518

STAGE END PRESSURE DROPS. PSF					TOTAL	REYNOLDS NUMBERS		
CONTRACTION		ENLARGEMENT			PRESSURE	ENTRANCE	CENTER	EXIT
FRICTION	MOMENTUM	FRICTION	MOMENTUM	TOTAL	DROP, PSF			
45.5	106.4	20.3	-145.9	26.3	299.7	44358.	40450.	36337.
52.3	122.4	23.6	-169.1	29.2	299.4	67634.	60953.	55077.
52.5	122.9	23.6	-169.5	29.5	299.7	67615.	61014.	55128.
52.6	123.1	23.7	-169.7	29.7	299.7	67845.	61235.	55339.
52.7	123.3	23.7	-169.8	29.8	299.7	68040.	61419.	55513.
52.7	123.3	23.7	-169.8	29.8	299.6	68161.	61531.	55619.
52.6	123.1	23.6	-169.6	29.8	299.3	68257.	61616.	55696.
52.7	123.3	23.7	-169.8	29.8	299.6	68316.	61668.	55743.
52.5	122.8	23.6	-169.4	29.4	299.5	67796.	61146.	55259.
49.3	115.4	22.5	-161.2	26.0	299.6	54620.	49247.	44316.
53.0	124.0	22.9	-164.0	35.9	299.6	65883.	60858.	55740.

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INPUT DATA, STAGE NO. 4
STAGE POWER= 1077.0 BTU/SEC
NUMBER OF RINGS=10
NUMBER OF SHIELDS= 1
STAGE LENGTH= 0.1250 FT.
ENTRANCE PRESSURE= 104405.9 PSF
HEAT LOSS= 0.1551 BTU/SEC

PASSAGE RADII,FT INNER	OUTER	F AREA,SQIN	S AREA,SQIN	RNG PWR DIST	EFF DIAM,IN	PWR DENSITY BTU/SEC SQIN	EMISSIVITY
0.01642	0.01983	0.055921	1.857057	0.00060	0.0818	0.3480	0.2300
0.02158	0.02683	0.114976	4.683357	0.04000	0.1260	9.1981	0.2600
0.02858	0.03383	0.148226	6.266718	0.05320	0.1260	9.1425	0.2600
0.03558	0.04083	0.181477	7.850079	0.06640	0.1260	9.1094	0.2600
0.04258	0.04783	0.214728	9.433441	0.07960	0.1260	9.0874	0.2600
0.04958	0.05483	0.247978	11.016802	0.09280	0.1260	9.0717	0.2600
0.05658	0.06183	0.281229	12.600163	0.10604	0.1260	9.0634	0.2600
0.06358	0.06883	0.314479	14.183525	0.11925	0.1260	9.0546	0.2600
0.07058	0.07583	0.347730	15.766886	0.13250	0.1260	9.0504	0.2600
0.07758	0.08233	0.343622	17.350247	0.14567	0.1140	9.0419	0.2600
0.08408	0.08792	0.298794	18.820511	0.15794	0.0922	9.0377	0.2600
0.08917	0.09917		9.943509	0.08600		0.6498	0.2300
							0.0500

PLATE TEMPERATURES FOR ALL INCREMENTS, DEGREES R

INCREMENT NO.	1	2	3	4	5	6	7	8	9	10
1	1181.3	1248.5	1295.0	1334.5	1371.0	1407.8	1439.6	1471.3	1503.9	1535.0
2	3003.1	3921.1	4214.2	4358.7	4446.3	4522.9	4553.1	4577.9	4618.8	4626.2
3	2871.3	3845.4	4178.9	4346.4	4446.8	4514.6	4563.5	4603.6	4673.5	4680.8
4	2860.4	3828.5	4160.9	4328.4	4428.8	4496.2	4545.4	4585.9	4656.8	4664.1
5	2851.5	3816.2	4147.5	4314.6	4414.8	4482.0	4531.0	4571.3	4642.0	4649.4
6	2845.1	3807.3	4137.8	4304.5	4404.6	4471.8	4520.6	4560.7	4631.2	4638.6
7	2841.2	3802.0	4132.0	4298.6	4398.6	4465.7	4514.5	4554.3	4624.8	4632.2
8	2838.3	3798.1	4127.9	4294.4	4394.4	4461.4	4510.2	4550.0	4620.4	4627.8
9	2844.0	3805.7	4135.9	4302.4	4402.4	4469.6	4518.7	4558.8	4629.0	4636.6
10	2947.7	3895.4	4213.8	4373.8	4471.4	4537.8	4587.5	4626.9	4686.9	4697.1
11	2876.9	3751.1	4033.5	4175.9	4264.9	4323.9	4382.1	4404.3	4432.5	4441.7
12	1006.8	1077.6	1118.1	1150.0	1178.5	1204.5	1231.4	1253.8	1276.6	1298.8
13	699.2	699.6	700.0	700.4	700.8	701.2	701.6	702.0	702.4	702.8
AV FUEL TEMP	2845.1	3783.7	4101.1	4260.7	4357.2	4422.5	4471.6	4507.4	4567.6	4575.3
AV GAS TEMP	1171.9	1204.3	1236.6	1268.8	1301.1	1333.3	1365.4	1397.5	1429.5	1461.4
DIFF IN TEMP	1673.2	2579.5	2864.5	2991.9	3056.1	3089.3	3106.2	3110.0	3138.2	3113.9

STAGE AVERAGE FUEL TEMP = 4189.2 DEG R
STAGE AVERAGE OUTLET GAS TEMP = 1493.3 DEG R
STAGE AVERAGE OUTLET DYNAMIC HEAD = 3.4607 PSI

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COMPUTED TEMPERATURES AND PRESSURES, STAGE NO. 4

	PLATE TEMPERATURES			GAS TEMPERATURES		
	ENTRANCE	CENTER	EXIT	ENTRANCE	CENTER	EXIT
CENTER PLUG	1181.	1371.	1535.	1116.	1269.	1426.
FUEL RINGS	3003.	4446.	4626.	1204.	1373.	1538.
	2871.	4447.	4681.	1205.	1372.	1538.
	2860.	4429.	4664.	1202.	1368.	1533.
	2852.	4415.	4649.	1199.	1364.	1529.
	2845.	4405.	4639.	1197.	1362.	1526.
	2841.	4399.	4632.	1195.	1360.	1524.
	2838.	4394.	4628.	1195.	1360.	1524.
	2844.	4402.	4637.	1201.	1371.	1536.
	2948.	4471.	4697.	1302.	1486.	1669.
	2877.	4265.	4442.	907.	1020.	1134.
RADTN SHIELDS	1007.	1178.	1299.			
CONTAINMNT SHELL	699.	701.	703.			

PASSAGE PRESSURE DROPS, PSF			MASS FLOW RATE			
FRICTION	MOMENTUM	TOTAL	LB/SEC-FT**2	PASSAGE WT FLOW, LB/SEC	EXIT MACH NO.	EXIT DYNAMIC HEAD, PSI
132.7	184.1	316.7	50.728	0.01970	0.0762	2.9187
85.4	222.1	307.5	53.611	0.04281	0.0838	3.5180
85.8	221.4	307.2	53.684	0.05525	0.0839	3.5260
85.8	221.3	307.1	53.784	0.06777	0.0839	3.5280
85.8	221.2	307.0	53.869	0.08032	0.0839	3.5299
85.8	221.2	307.0	53.926	0.09285	0.0839	3.5310
85.7	221.2	306.9	53 966	0.10539	0.0839	3.5308
85.7	221.3	307 0	53.966	0.11784	0.0839	3.5307
85.5	221.7	307.2	53.658	0.12962	0.0838	3.5192
97.4	213.5	310.9	50.185	0.11976	0.0818	3.3444
114.4	191.8	306.2	60.379	0.12528	0.0808	3.2904

STAGE END PRESSURE DROPS, PSF					TOTAL	REYNOLDS NUMBERS		
CONTRACTION		ENLARGEMENT			PRESSURE	ENTRANCE	CENTER	EXIT
FRICTION	MOMENTUM	FRICTION	MOMENTUM	TOTAL	DROP, PSF			
60.1	140.6	25.2	-180.5	45.3	362.1	35029.	32668.	30214.
72.3	169.3	30.3	-217.5	54.4	362.0	54171.	50447.	46724.
72.6	169.9	30.4	-218.0	54.9	362.1	54208.	50532.	46804.
72.7	170.1	30.4	-218 1	55.0	362.1	54412.	50723.	46985.
72.7	170.2	30.4	-218.2	55.1	362.1	54586.	50884.	47142.
72.8	170.3	30.4	-218.3	55.2	362.1	54706.	50994.	47248.
72.8	170.3	30.4	-218.3	55.2	362.1	54805.	51082.	47333.
72.7	170.2	30.4	-218.3	55.1	362.1	54813.	51086.	47334.
72.4	169.4	30.3	-217.6	54.6	361.8	54248.	50541.	46809.
68.6	160.5	28.8	-206.8	51.1	362.0	43495.	40584.	37586.
69.1	161.8	28.4	-203.4	55.8	362.1	54465.	50656.	47086.

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INPUT DATA. STAGE NO. 5
STAGE POWER= 1057.2 BTU/SEC
NUMBER OF RINGS=10
NUMBER OF SHIELDS= 1
STAGE LENGTH= 0.1250 FT.
ENTRANCE PRESSURE= 104043.8 PSF
HEAT LOSS= 0.2429 BTU/SEC

PASSAGE RADII.FT INNER	OUTER	F AREA.SQIN	S AREA.SQIN	RNG PWR DIST	EFF	DIAM,IN	PWR DENSITY BTU/SEC/SQIN	EMISSIVITY
0.01642	0.01983	0.055921	1.857057	0.00060	0.0818		0.3416	0.2300
0.02158	0.02683	0.114976	4.683357	0.04000	0.1260		9.0295	0.2600
0.02858	0.03383	0.148226	6.266718	0.05320	0.1260		8.9749	0.2600
0.03558	0.04083	0.181477	7.850079	0.06640	0.1260		8.9424	0.2600
0.04258	0.04783	0.214728	9.433441	0.07960	0.1260		8.9208	0.2600
0.04958	0.05483	0.247978	11.016802	0.09280	0.1260		8.9054	0.2600
0.05658	0.06183	0.281229	12.600163	0.10604	0.1260		8.8972	0.2600
0.06358	0.06883	0.314479	14.183525	0.11925	0.1260		8.8886	0.2600
0.07058	0.07583	0.347730	15.766886	0.13250	0.1260		8.8844	0.2600
0.07758	0.08233	0.343622	17.350247	0.14567	0.1140		8.8761	0.2600
0.08408	0.08792	0.298794	18.820511	0.15794	0.0922		8.8720	0.2600
0.08917	0.09917		9.943509	0.00600			0.6379	0.2300
								0.0500

PLATE TEMPERATURES FOR ALL INCREMENTS. DEGREES R

INCREMENT NO.	1	2	3	4	5	6	7	8	9	10
1	1488.0	1551.5	1595.6	1633.6	1669.1	1704.9	1736.5	1768.1	1800.5	1831.7
2	3113.4	3906.1	4166.7	4301.9	4388.1	4465.0	4503.0	4536.5	4583.7	4602.1
3	3009.4	3846.0	4138.1	4292.5	4391.1	4462.1	4515.9	4566.2	4639.1	4658.2
4	2999.4	3831.4	4122.4	4276.5	4375.0	4445.6	4502.6	4550.1	4623.7	4642.7
5	2997.2	3819.4	4109.5	4267.8	4361.1	4431.5	4487.9	4535.3	4608.7	4627.6
6	2983.4	3810.7	4100.1	4252.8	4350.9	4421.1	4477.1	4524.4	4597.7	4616.5
7	2978.9	3805.2	4094.3	4245.5	4344.5	4414.7	4470.4	4517.7	4590.8	4609.5
8	2976.2	3801.7	4090.6	4242.8	4340.7	4410.8	4466.5	4513.7	4586.8	4605.5
9	2984.6	3811.6	4101.0	4254.0	4352.1	4422.6	4479.1	4526.5	4599.5	4618.6
10	3097.3	3913.7	4195.7	4345.2	4441.7	4512.0	4568.9	4615.7	4679.4	4698.7
11	2989.7	3748.0	3997.2	4126.1	4209.5	4270.1	4330.7	4359.0	4391.0	4406.2
12	1229.2	1296.4	1334.8	1365.5	1393.3	1419.3	1446.2	1469.2	1492.4	1515.0
13	703.1	703.4	703.7	704.0	704.3	704.6	704.9	705.2	705.5	705.8
AV FUEL TEMP	2975.6	3784.0	4063.0	4209.7	4303.9	4372.2	4427.8	4470.9	4534.4	4552.3
AV GAS TEMP	1493.3	1524.6	1555.8	1587.0	1618.1	1649.1	1680.1	1711.1	1742.0	1772.8
DIFF IN TEMP	1482.3	2259.4	2507.2	2622.7	2685.8	2723.0	2747.7	2759.8	2792.4	2779.5

STAGE AVERAGE FUEL TEMP = 4169.4 DEG R
STAGE AVERAGE OUTLET GAS TEMP = 1803.8 DEG R
STAGE AVERAGE OUTLET DYNAMIC HEAD = 4.1987 PSI

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COMPUTED TEMPERATURES AND PRESSURES. STAGE NO. 5

	PLATE TEMPERATURES			GAS TEMPERATURES		
	ENTRANCE	CENTER	EXIT	ENTRANCE	CENTER	EXIT
CENTER PLUG	1488.	1669.	1832.	1426.	1576.	1730.
FUEL RINGS	3113.	4388.	4602.	1538.	1700.	1859.
	3009.	4391.	4658.	1538.	1698.	1858.
	2989.	4375.	4643.	1533.	1693.	1852.
	2990.	4361.	4628.	1529.	1688.	1847.
	2983.	4351.	4616.	1526.	1685.	1843.
	2979.	4345.	4610.	1524.	1683.	1840.
	2976.	4341.	4606.	1524.	1683.	1841.
	2985.	4352.	4619.	1537.	1699.	1859.
	3097.	4442.	4699.	1664.	1837.	2009.
	2990.	4210.	4406.	1134.	1249.	1365.
RADTN SHIELDS	1229.	1393.	1515.			
CONTAINMNT SHELL	703.	704.	706.			

PASSAGE PRESSURE DROPS,PSF			MASS FLOW RATE			
FRICTION	MOMENTUM	TOTAL	LB/SEC-FT**2	PASSAGE WT FLOW,LB/SEC	EXIT MACH NO.	EXIT DYNAMIC HEAD,PSI
179.0	177.5	356.5	50.046	0.01939	0.0834	3.4616
121.5	216.4	337.9	53.737	0.04289	0.0930	4.2914
121.7	215.7	337.4	53.777	0.05537	0.0931	4.2942
121.7	215.6	337.3	53.880	0.06792	0.0931	4.2964
121.6	215.6	337.2	53.964	0.08049	0.0931	4.2981
121.6	215.6	337.2	54.022	0.09305	0.0931	4.2993
121.5	215.7	337.2	54.066	0.10561	0.0931	4.2998
121.5	215.9	337.3	54.055	0.11806	0.0931	4.2991
121.4	216.7	338.1	53.722	0.12964	0.0930	4.2893
137.6	203.6	341.2	50.305	0.12030	0.0907	4.0631
153.2	191.9	345.1	59.807	0.12389	0.0883	3.9005

STAGE END PRESSURE DROPS, PSF					TOTAL	REYNOLDS NUMBERS		
CONTRACTION		ENLARGEMENT			PRESSURE	ENTRANCE	CENTER	EXIT
FRICTION	MOMENTUM	FRICTION	MOMENTUM	TOTAL	DROP,PSF			
74.9	175.4	29.8	-214.0	66.1	422.6	29373.	27856.	26264.
93.2	218.0	37.0	-265.3	82.9	420.8	46204.	43910.	41375.
93.3	218.3	37.0	-265.5	83.2	420.6	46239.	43970.	41430.
93.4	218.5	37.0	-265.6	83.3	420.6	46421.	44142.	41593.
93.4	218.6	37.0	-265.7	83.3	420.6	46572.	44282.	41728.
93.4	218.7	37.0	-265.8	83.4	420.6	46676.	44380.	41821.
93.4	218.7	37.1	-265.8	83.4	420.6	46760.	44457.	41894.
93.4	218.6	37.0	-265.8	83.3	420.6	46749.	44444.	41879.
93.1	217.8	37.0	-265.2	82.7	420.8	46201.	43910.	41364.
88.3	206.7	35.0	-251.2	78.9	420.1	37248.	35344.	33350.
85.1	199.3	33.6	-241.1	76.9	422.0	46008.	43646.	41121.

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INPUT DATA. STAGE NO. 6
STAGE POWER= 1019.2 BTU/SEC
NUMBER OF RINGS=10
NUMBER OF SHIELDS= 1
STAGE LENGTH= 0.1250 FT.
ENTRANCE PRESSURE= 103623.0 PSF
HEAT LOSS= 0.3451 BTU/SEC

PASSAGE RADII,FT INNER	OUTER	F AREA,SQIN	S AREA,SQIN	RNG PWR DIST	EFF	DIAM,IN	PWR DENSITY BTU/SEC SQIN	EMISSIVITY
0.01642	0.01983	0.055921	1.857057	0.00060	0.0818		0.3293	0.2300
0.02158	0.02683	0.114976	4.683357	0.04000	0.1260		8.7051	0.2600
0.02858	0.03383	0.148226	6.266718	0.05320	0.1260		8.6525	0.2600
0.03558	0.04083	0.181477	7.850079	0.06640	0.1260		8.6212	0.2600
0.04258	0.04783	0.214728	9.433441	0.07960	0.1260		8.6003	0.2600
0.04958	0.05483	0.247978	11.016802	0.09280	0.1260		8.5853	0.2600
0.05658	0.06183	0.281229	12.600163	0.10604	0.1260		8.5776	0.2600
0.06358	0.06883	0.314479	14.183525	0.11925	0.1260		8.5693	0.2600
0.07058	0.07583	0.347730	15.766886	0.13250	0.1260		8.5653	0.2600
0.07758	0.08233	0.343622	17.350247	0.14567	0.1140		8.5573	0.2600
0.08408	0.08792	0.298794	18.820511	0.15794	0.0922		8.5533	0.2600
0.08917	0.09917		9.943509	0.00600			0.6150	0.2300
								0.0500

PLATE TEMPERATURES FOR ALL INCREMENTS, DEGREES R

INCREMENT NO.	1	2	3	4	5	6	7	8	9	10
1	1789.5	1850.0	1892.0	1928.6	1962.8	1997.4	2028.0	2058.4	2089.4	2119.5
2	3260.3	3957.9	4192.4	4317.5	4400.1	4474.8	4513.9	4547.6	4593.3	4613.9
3	3178.9	3914.8	4176.1	4315.2	4407.9	4475.7	4529.1	4574.0	4641.3	4661.9
4	3168.7	3900.8	4161.3	4301.2	4392.8	4460.2	4513.9	4558.9	4626.7	4647.2
5	3158.6	3888.2	4148.2	4287.6	4379.0	4446.2	4499.7	4544.6	4612.2	4632.5
6	3151.1	3878.9	4138.4	4277.5	4368.7	4435.8	4489.2	4534.0	4601.4	4621.6
7	3146.2	3872.9	4132.3	4271.3	4362.3	4429.3	4482.6	4527.4	4594.7	4614.7
8	3143.8	3869.9	4129.2	4268.1	4359.1	4426.1	4479.4	4524.2	4591.5	4611.5
9	3156.2	3884.1	4143.4	4282.6	4374.0	4441.2	4494.7	4539.7	4607.2	4627.7
10	3275.7	3992.7	4243.4	4378.1	4467.0	4533.0	4586.3	4630.9	4691.0	4712.5
11	3114.6	3778.2	3999.0	4115.1	4193.2	4250.2	4307.6	4336.4	4369.2	4387.8
12	1457.6	1516.4	1553.2	1583.1	1610.1	1635.6	1661.8	1684.6	1707.5	1730.1
13	706.1	706.4	706.7	707.0	707.3	707.6	707.9	708.2	708.5	708.8
AV FUEL TEMP	3134.3	3845.0	4094.5	4227.9	4315.5	4380.5	4433.5	4474.8	4534.2	4554.1
AV GAS TEMP	1803.8	1833.4	1862.9	1892.4	1921.9	1951.2	1980.5	2009.8	2039.0	2068.2
DIFF IN TEMP	1330.6	2011.7	2231.5	2335.5	2393.6	2429.3	2452.9	2465.0	2495.2	2485.9

STAGE AVERAGE FUEL TEMP = 4199.4 DEG R
STAGE AVERAGE OUTLET GAS TEMP = 2097.4 DEG R
STAGE AVERAGE OUTLET DYNAMIC HEAD = 4.9087 PSI

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COMPUTED TEMPERATURES AND PRESSURES. STAGE NO. 6

	PLATE TEMPERATURES			GAS TEMPERATURES		
	ENTRANCE	CENTER	EXIT	ENTRANCE	CENTER	EXIT
CENTER PLUG	1789.	1963.	2120.	1730.	1875.	2022.
FUEL RINGS	3260.	4400.	4614.	1859.	2012.	2162.
	3179.	4408.	4662.	1858.	2009.	2160.
	3169.	4393.	4647.	1852.	2003.	2152.
	3159.	4379.	4632.	1846.	1997.	2146.
	3151.	4369.	4622.	1843.	1993.	2142.
	3146.	4362.	4615.	1840.	1990.	2139.
	3144.	4359.	4612.	1841.	1991.	2140.
	3156.	4374.	4628.	1861.	2014.	2165.
	3276.	4467.	4713.	2003.	2161.	2320.
	3115.	4193.	4388.	1365.	1479.	1593.
RADTN SHIELDS	1453.	1610.	1730.			
CONTAINMNT SHELL	706.	707.	709.			

PASSAGE PRESSURE DROPS, PSF			MASS FLOW RATE			
FRICTION	MOMENTUM	TOTAL	LB/SEC-FT**2	PASSAGE WT FLOW, LB/SEC	EXIT MACH NO.	EXIT DYNAMIC HEAD, PSI
225.0	168.1	393.1	49.397	0.01914	0.0898	3.9617
159.2	207.0	366.2	53.845	0.04296	0.1014	5.0355
159.3	206.4	365.7	53.879	0.05544	0.1014	5.0369
159.2	206.5	365.7	53.982	0.06801	0.1015	5.0391
159.1	206.5	365.6	54.068	0.08059	0.1015	5.0410
159.1	206.5	365.5	54.127	0.09318	0.1015	5.0424
159.0	206.6	365.6	54.169	0.10575	0.1015	5.0430
158.9	206.8	365.8	54.147	0.11817	0.1015	5.0419
158.9	207.6	366.5	53.774	0.13019	0.1014	5.0304
179.1	190.8	369.9	50.508	0.12070	0.0987	4.7539
193.1	187.8	380.9	59.123	0.12248	0.0949	4.4714

STAGE END PRESSURE DROPS, PSF					TOTAL	REYNOLDS NUMBERS		
CONTRACTION		ENLARGEMENT			PRESSURE	ENTRANCE	CENTER	EXIT
FRICTION	MOMENTUM	FRICTION	MOMENTUM	TOTAL	DROP, PSF			
88.9	208.1	34.1	-244.9	86.3	479.3	25614.	24557.	23371.
113.5	265.7	43.4	-311.2	111.3	477.5	41030.	39368.	37590.
113.6	265.9	43.4	-311.3	111.5	477.3	41169.	39424.	37639.
113.7	266.0	43.4	-311.5	111.6	477.3	41232.	39586.	37789.
113.7	266.1	43.4	-311.6	111.7	477.3	41367.	39721.	37915.
113.7	266.2	43.4	-311.7	111.7	477.3	41460.	39814.	38002.
113.8	266.2	43.5	-311.7	111.7	477.3	41531.	39884.	38065.
113.7	266.1	43.4	-311.6	111.6	477.4	41505.	39856.	38036.
113.9	265.2	43.3	-310.9	111.0	477.5	40950.	39286.	37504.
107.6	251.9	41.0	-293.9	106.6	476.5	33179.	31925.	30471.
100.5	235.2	38.5	-276.4	97.8	478.7	40210.	38529.	36688.

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INPUT DATA. STAGE NO. 7
STAGE POWER= 966.1 BTU/SEC
NUMBER OF RINGS=10
NUMBER OF SHIELDS= 1
STAGE LENGTH= 0.1250 FT.
ENTRANCE PRESSURE= 103145.4 PSF
HEAT LOSS= 0.4583 BTU/SEC

PASSAGE RADII,FT INNER	OUTER	P AREA,SQIN	S AREA,SQIN	RNG PWR DIST	EFF DIAM,IN	PWR DENSITY BTU/SECSQIN	EMISSIVITY
0.01642	0.01983	0.055921	1.857057	0.00060	0.0818	0.3121	0.2300
0.02158	0.02683	0.114976	4.683357	0.04000	0.1260	8.2511	0.2600
0.02858	0.03383	0.148226	6.266718	0.05320	0.1260	8.2012	0.2600
0.03558	0.04083	0.181477	7.850079	0.06640	0.1260	8.1715	0.2600
0.04258	0.04783	0.214728	9.433441	0.07960	0.1260	8.1517	0.2600
0.04958	0.05483	0.247978	11.016802	0.09280	0.1260	8.1377	0.2600
0.05658	0.06183	0.281229	12.600163	0.10604	0.1260	8.1302	0.2600
0.06358	0.06883	0.314479	14.183525	0.11925	0.1260	8.1223	0.2600
0.07058	0.07583	0.347730	15.766886	0.13250	0.1260	8.1185	0.2600
0.07758	0.08233	0.343622	17.350247	0.14567	0.1140	8.1109	0.2600
0.08408	0.08792	0.298794	18.820511	0.15794	0.0922	8.1071	0.2600
0.08917	0.09917		9.943509	0.00600		0.5829	0.2300
							0.0500

PLATE TEMPERATURES FOR ALL INCREMENTS, DEGREES R

INCREMENT NO. M	1	2	3	4	5	6	7	8	9	10
1	2079.1	2136.3	2175.5	2209.7	2241.7	2274.2	2303.0	2331.7	2361.0	2389.5
2	3409.4	4021.6	4228.8	4340.9	4416.3	4484.9	4522.8	4556.6	4600.8	4622.6
3	3343.0	3987.2	4217.3	4342.9	4426.6	4489.6	4540.9	4584.8	4648.2	4669.8
4	3332.8	3973.9	4203.2	4328.6	4412.2	4474.9	4526.2	4570.3	4634.0	4655.8
5	3322.4	3961.3	4190.0	4314.9	4398.3	4460.8	4511.9	4555.8	4619.4	4641.2
6	3314.6	3952.0	4180.1	4304.8	4388.0	4450.4	4501.2	4545.0	4608.4	4630.3
7	3309.4	3946.1	4173.9	4298.4	4381.5	4443.8	4494.5	4538.2	4601.6	4623.4
8	3307.6	3943.8	4171.5	4296.0	4379.1	4441.4	4492.1	4535.9	4599.3	4621.1
9	3323.2	3960.9	4189.2	4314.1	4397.5	4460.1	4511.3	4555.3	4618.7	4640.5
10	3442.1	4070.0	4291.4	4412.4	4493.2	4554.2	4604.4	4647.5	4704.6	4727.4
11	3236.5	3817.1	4012.9	4118.8	4189.4	4242.8	4297.4	4326.9	4360.2	4381.5
12	1673.4	1733.4	1768.3	1796.8	1822.8	1847.4	1872.8	1895.0	1917.4	1939.6
13	709.1	709.4	709.7	710.0	710.3	710.6	710.9	711.2	711.5	711.8
AV FUEL TEMP	3289.1	3911.7	4131.5	4251.4	4331.4	4391.9	4442.4	4483.1	4539.6	4561.2
AV GAS TEMP	2097.4	2125.0	2152.4	2179.8	2207.2	2234.5	2261.7	2288.8	2315.9	2343.0
DIFF IN TEMP	1191.7	1786.7	1979.1	2071.5	2124.2	2157.5	2180.7	2194.2	2223.6	2218.2

STAGE AVERAGE FUEL TEMP = 4233.3 DEG R
STAGE AVERAGE OUTLET GAS TEMP = 2370.1 DEG R
STAGE AVERAGE OUTLET DYNAMIC HEAD = 5.5805 PSI

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COMPUTED TEMPERATURES AND PRESSURES, STAGE NO. 7

	PLATE TEMPERATURES			GAS TEMPERATURES		
	ENTRANCE	CENTER	EXIT	ENTRANCE	CENTER	EXIT
CENTER PLUG	2079.	2242.	2389.	2022.	2159.	2298.
FUEL RINGS	3409.	4416.	4623.	2161.	2303.	2442.
	3343.	4427.	4670.	2160.	2300.	2439.
	3333.	4412.	4656.	2152.	2293.	2431.
	3322.	4398.	4641.	2146.	2286.	2424.
	3315.	4388.	4630.	2142.	2282.	2420.
	3309.	4382.	4623.	2139.	2279.	2416.
	3308.	4379.	4621.	2141.	2280.	2419.
	3323.	4397.	4641.	2166.	2309.	2449.
	3442.	4491.	4727.	2313.	2455.	2599.
	3236.	4189.	4381.	1593.	1704.	1814.
RADTN SHIELDS	1673.	1873.	1940.			
CONTAINMNT SHELL	709.	710.	712.			

PASSAGE PRESSURE DROPS, PSF			MASS FLOW RATE			
FRICTION	MOMENTUM	TOTAL	LB/SEC-FT**2	PASSAGE WT FLOW, LB/SEC	EXIT MACH NO.	EXIT DYNAMIC HEAD, PSI
270.3	157.0	427.3	48.856	0.01894	0.0955	4.4275
197.4	194.6	392.0	53.936	0.04305	0.1090	5.7391
197.5	194.2	391.7	53.968	0.05558	0.1090	5.7403
197.3	194.3	391.6	54.070	0.06818	0.1090	5.7426
197.2	194.4	391.6	54.156	0.08080	0.1090	5.7445
197.2	194.4	391.5	54.215	0.09341	0.1090	5.7461
197.1	194.5	391.6	54.255	0.10601	0.1090	5.7467
197.0	194.9	391.8	54.220	0.11814	0.1090	5.7449
197.1	195.3	392.5	53.820	0.12998	0.1089	5.7316
220.5	176.0	396.5	50.751	0.12136	0.1060	5.4072
233.4	180.6	414.0	58.465	0.12117	0.1009	5.0086

STAGE END PRESSURE DROPS, PSF					TOTAL	REYNOLDS NUMBERS		
CONTRACTION		ENLARGEMENT			PRESSURE	ENTRANCE	CENTER	EXIT
FRICTION	MOMENTUM	FRICTION	MOMENTUM	TOTAL	DROP, PSF			
102.2	239.1	38.2	-273.7	105.7	533.0	22900.	22159.	21276.
133.1	311.4	49.4	-354.7	139.2	531.2	37334.	36106.	34721.
133.1	311.6	49.5	-354.8	139.4	531.1	37373.	36157.	34765.
133.2	311.7	49.5	-354.9	139.4	531.1	37523.	36307.	34905.
133.2	311.8	49.5	-355.0	139.5	531.1	37648.	36432.	35024.
133.3	311.9	49.5	-355.1	139.5	531.1	37734.	36519.	35108.
133.3	311.9	49.5	-355.2	139.5	531.1	37795.	36579.	35165.
133.2	311.7	49.5	-355.1	139.3	531.1	37755.	36536.	35121.
132.8	310.8	49.4	-354.2	138.7	531.2	37199.	35968.	34582.
126.1	295.1	46.6	-334.2	133.5	530.0	30403.	29462.	28367.
115.2	269.7	43.2	-309.6	118.4	532.4	35941.	34760.	33331.

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INPUT DATA. STAGE NO. 8
STAGE POWER= 902.3 BTU/SEC
NUMBER OF RINGS=10
NUMBER OF SHIELDS= 1
STAGE LENGTH= 0.1250 FT.
ENTRANCE PRESSURE= 102614.1 PSF
HEAT LOSS= 0.5783 BTU/SEC

PASSAGE RADII,FT INNER	OUTER	F AREA,SQIN	S AREA,SQIN	RNG PWR DIST	EFF	DIAM,IN	PWR DENSITY BTU/SEC SQIN	EMISSIVITY
0.01642	0.01983	0.055921	1.857057	0.00060		0.0818	0.2915	0.2300
0.02158	0.02683	0.114976	4.683357	0.04000		0.1260	7.7062	0.2600
0.02858	0.03383	0.148226	6.266718	0.05320		0.1260	7.6596	0.2600
0.03558	0.04083	0.181477	7.850079	0.06640		0.1260	7.6319	0.2600
0.04258	0.04783	0.214728	9.433441	0.07960		0.1260	7.6134	0.2600
0.04958	0.05483	0.247978	11.016802	0.09280		0.1260	7.6003	0.2600
0.05658	0.06183	0.281229	12.600163	0.10604		0.1260	7.5933	0.2600
0.06358	0.06883	0.314479	14.183525	0.11925		0.1260	7.5860	0.2600
0.07058	0.07583	0.347730	15.766886	0.13250		0.1260	7.5824	0.2600
0.07758	0.08233	0.343622	17.350247	0.14567		0.1140	7.5753	0.2600
0.08408	0.08792	0.298794	18.820511	0.15794		0.0922	7.5718	0.2600
0.08917	0.09917		9.943509	0.00600			0.5444	0.2300
								0.0500

PLATE TEMPERATURES FOR ALL INCREMENTS. DEGREES R

INCREMENT NO. M	1	2	3	4	5	6	7	8	9	10
1	2351.3	2404.7	2440.9	2472.5	2502.1	2532.1	2558.7	2585.3	2617.4	2638.8
2	3547.9	4084.8	4267.6	4368.5	4437.3	4500.2	4535.9	4568.1	4609.2	4631.7
3	3496.2	4060.9	4262.8	4375.2	4451.5	4510.0	4557.8	4599.0	4657.2	4679.2
4	3486.2	4048.2	4249.6	4361.4	4437.7	4495.9	4543.8	4585.2	4643.7	4665.8
5	3475.4	4035.7	4236.4	4347.5	4423.5	4481.6	4529.3	4570.6	4629.0	4651.0
6	3467.2	4026.2	4226.5	4337.1	4412.8	4470.8	4518.4	4559.6	4617.9	4639.8
7	3461.9	4020.2	4220.3	4330.8	4406.2	4464.0	4511.6	4552.8	4611.0	4633.0
8	3460.7	4018.7	4218.7	4329.2	4404.7	4462.5	4510.2	4551.4	4609.7	4631.6
9	3479.5	4038.8	4239.4	4350.9	4426.8	4485.0	4532.8	4574.7	4632.5	4654.6
10	3594.5	4145.2	4339.9	4448.2	4521.8	4578.1	4624.8	4664.9	4716.9	4739.4
11	3355.5	3865.0	4038.1	4133.4	4198.0	4247.2	4297.3	4324.6	4354.7	4375.0
12	1887.9	1943.9	1976.7	2003.7	2028.3	2051.7	2075.6	2096.7	2118.0	2138.9
13	712.1	712.3	712.5	712.7	712.9	713.1	713.3	713.5	713.7	713.9
AV FUEL TEMP	3434.9	3981.0	4174.4	4281.4	4354.3	4410.5	4457.6	4495.8	4547.7	4569.3
AV GAS TEMP	2370.1	2395.3	2420.4	2445.5	2470.5	2495.5	2520.4	2545.3	2570.1	2594.9
DIFF IN TEMP	1064.8	1585.7	1754.0	1835.9	1883.8	1915.0	1937.2	1950.6	1977.6	1974.4

STAGE AVERAGE FUEL TEMP = 4270.7 DEG R
STAGE AVERAGE OUTLET GAS TEMP = 2619.8 DEG R
STAGE AVERAGE OUTLET DYNAMIC HEAD = 6.2092 PSI

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COMPUTED TEMPERATURES AND PRESSURES, STAGE NO. 8

	PLATE TEMPERATURES			GAS TEMPERATURES		
	ENTRANCE	CENTER	EXIT	ENTRANCE	CENTER	EXIT
CENTER PLUG	2351	2502.	2639.	2298.	2424.	2553.
FUEL RINGS	3548.	4437.	4632.	2441.	2570.	2697.
	3496.	4452.	4679.	2439.	2568.	2695.
	3486.	4438.	4666.	2431.	2559.	2686.
	3475.	4424.	4651.	2424.	2552.	2678.
	3467.	4413.	4640.	2420.	2547.	2673.
	3462.	4406.	4633.	2416.	2544.	2670.
	3461.	4405.	4632.	2419.	2547.	2673.
	3479.	4427.	4655.	2450.	2580.	2708.
	3595.	4522.	4739.	2592.	2718.	2846.
	3355.	4198.	4375.	1814.	1922.	2026.
RADTN SHIELDS	1888.	2028.	2139.			
CONTAINMNT SHELL	712.	713.	714.			

PASSAGE PRESSURE DROPS, PSF			MASS FLOW RATE			
FRICTION	MOMENTUM	TOTAL	LB/SEC-FT**2	PASSAGE WT FLOW, LB/SEC	EXIT MACH NO.	EXIT DYNAMIC HEAD, PSI
314.1	144.9	459.1	48.413	0.01877	0.1007	4.8591
235.1	180.6	415.7	54.016	0.04296	0.1158	6.3973
235.0	180.5	415.5	54.044	0.05564	0.1158	6.3982
234.8	180.6	415.4	54.144	0.06824	0.1158	6.4007
234.7	180.7	415.4	54.230	0.08087	0.1158	6.4030
234.6	180.7	415.3	54.290	0.09350	0.1158	6.4047
234.5	180.9	415.4	54.327	0.10612	0.1158	6.4053
234.4	181.3	415.7	54.280	0.11857	0.1158	6.4027
234.7	181.5	416.2	53.863	0.13008	0.1158	6.3884
260.6	160.8	421.4	50.997	0.12195	0.1125	6.0164
273.1	171.4	444.4	57.855	0.11991	0.1065	5.5104

STAGE END PRESSURE DROPS, PSF					TOTAL	REYNOLDS NUMBERS		
CONTRACTION		ENLARGEMENT			PRESSURE	ENTRANCE	CENTER	EXIT
FRICTION	MOMENTUM	FRICTION	MOMENTUM	TOTAL	DROP, PSF			
114.6	268.1	41.9	-300.3	124.2	583.3	20911.	20327.	19652.
151.5	354.6	55.1	-395.3	165.9	581.6	34526.	33596.	32550.
151.6	354.7	55.1	-395.4	166.0	581.5	34561.	33639.	32586.
151.6	354.8	55.1	-395.5	166.0	581.5	34700.	33779.	32715.
151.7	355.0	55.2	-395.7	166.1	581.5	34817.	33897.	32825.
151.7	355.1	55.2	-395.8	166.1	581.5	34899.	33979.	32901.
151.7	355.1	55.2	-395.8	166.1	581.5	34953.	34032.	32950.
151.6	354.8	55.2	-395.7	165.9	581.6	34900.	33975.	32895.
151.2	353.9	55.0	-394.8	165.4	581.6	34350.	33415.	32373.
143.4	335.6	51.8	-371.8	159.0	580.3	28345.	27670.	26842.
129.2	302.4	47.5	-340.6	138.5	582.9	32728.	31799.	30698.

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INPUT DATA. STAGE NO. 9
STAGE POWER= 833.9 BTU/SEC
NUMBER OF RINGS=10
NUMBER OF SHIELDS= 1
STAGE LENGTH= 0.1250 FT.
ENTRANCE PRESSURE= 102032.4 PSF
HEAT LOSS= 0.7026 BTU/SEC

PASSAGE RADII,FT	INNER	OUTER	F AREA,SQIN	S AREA,SQIN	RNG PWR DIST	EFF DIAM,IN	PWR DENSITY BTU/SEC SQIN	EMISSIVITY
	0.01642	0.01983	0.055921	1.857057	0.00060	0.0818	0.2694	0.2300
	0.02158	0.02683	0.114976	4.683357	0.04000	0.1260	7.1224	0.2600
	0.02858	0.03383	0.148226	6.266718	0.05320	0.1260	7.0793	0.2600
	0.03558	0.04083	0.181477	7.850079	0.06640	0.1260	7.0537	0.2600
	0.04258	0.04783	0.214728	9.433441	0.07960	0.1260	7.0366	0.2600
	0.04958	0.05483	0.247978	11.016802	0.09280	0.1260	7.0245	0.2600
	0.05658	0.06183	0.281229	12.600163	0.10604	0.1260	7.0180	0.2600
	0.06358	0.06883	0.314479	14.183525	0.11925	0.1260	7.0113	0.2600
	0.07058	0.07583	0.347730	15.766886	0.13250	0.1260	7.0080	0.2600
	0.07758	0.08233	0.343622	17.350247	0.14567	0.1140	7.0014	0.2600
	0.08408	0.08792	0.298794	18.820511	0.15794	0.0922	6.9981	0.2600
	0.08917	0.09917		9.943509	0.00600		0.5032	0.2300
								0.0500

PLATE TEMPERATURES FOR ALL INCREMENTS. DEGREES R

INCREMENT NO.	1	2	3	4	5	6	7	8	9	10
1	2603.1	2652.6	2685.9	2714.9	2742.0	2769.5	2794.0	2818.4	2843.2	2867.4
2	3678.7	4151.0	4312.9	4402.7	4464.5	4521.5	4555.1	4585.5	4623.8	4645.1
3	3639.3	4136.8	4315.5	4415.1	4482.9	4535.5	4579.2	4617.3	4670.4	4691.7
4	3629.4	4124.7	4302.9	4402.3	4470.0	4522.2	4566.0	4604.3	4657.6	4679.0
5	3618.1	4111.8	4289.4	4388.5	4456.0	4507.9	4551.5	4589.6	4642.8	4664.1
6	3609.5	4102.0	4279.2	4378.1	4445.5	4497.2	4540.4	4578.5	4631.5	4652.8
7	3604.0	4095.9	4272.9	4371.7	4438.9	4490.6	4533.7	4571.7	4624.6	4645.9
8	3603.5	4095.3	4272.3	4371.1	4438.4	4490.1	4533 2	4571.3	4624.3	4645.6
9	3625.5	4118.5	4296.0	4395.1	4462.7	4515.1	4558.7	4596.9	4650.0	4671.4
10	3733.4	4218.0	4389.8	4485.7	4551.3	4602.4	4645.0	4682.1	4729.1	4750.0
11	3465.4	3911.6	4063.5	4147.6	4205.2	4250.0	4295.9	4321.4	4349.1	4368.2
12	2092.4	2144.1	2174.5	2199.6	2222.7	2244.6	2267.1	2287.0	2307.1	2326.8
13	714.1	714.3	714.5	714.7	714.9	715.1	715.3	715.5	715.7	715.9
AV FUEL TEMP	3571.0	4051.8	4222.7	4317.9	4383.0	4433.5	4476.6	4512.0	4559.3	4580.1
AV GAS TEMP	2619.8	2642.6	2665.4	2688.1	2710.8	2733.5	2756.1	2778.7	2801.3	2823.8
DIFF IN TEMP	951.3	1409.2	1557.3	1629.8	1672.1	1700.1	1720.5	1733.3	1758.0	1756.3

STAGE AVERAGE FUEL TEMP = 4310.8 DEG R
STAGE AVERAGE OUTLET GAS TEMP = 2846.4 DEG R
STAGE AVERAGE OUTLET DYNAMIC HEAD = 6.7945 PSI

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COMPUTED TEMPERATURES AND PRESSURES. STAGE NO. 9

	PLATE TEMPERATURES			GAS TEMPERATURES		
	ENTRANCE	CENTER	EXIT	ENTRANCE	CENTER	EXIT
CENTER PLUG	2603.	2742.	2867.	2553.	2669.	2787.
FUEL RINGS	3679.	4464.	4645.	2697.	2813.	2928.
	3639.	4483.	4692.	2695.	2811.	2926.
	3629.	4470.	4679.	2686.	2801.	2916.
	3618.	4456.	4664.	2678.	2794.	2908.
	3609.	4445.	4653.	2673.	2788.	2903.
	3604.	4439.	4646.	2670.	2785.	2899.
	3604.	4438.	4646.	2673.	2789.	2904.
	3626.	4463.	4671.	2709.	2827.	2943.
	3733.	4551.	4750.	2839.	2950.	3064.
	3465.	4205.	4368.	2026.	2128.	2227.
RADTN SHIELDS	2092.	2223.	2327.			
CONTAINMNT SHELL	714.	715.	716.			

PASSAGE PRESSURE DROPS,PSF			MASS FLOW RATE			
FRICTION	MOMENTUM	TOTAL	LB/SEC-FT**2	PASSAGE WT FLOW,LB/SEC	EXIT MACH NO.	EXIT DYNAMIC HEAD,PSI
355.8	133.3	489.1	48.047	0.01864	0.1054	5.2589
271.2	166.7	437.9	54.089	0.04317	0.1219	7.0103
271.1	166.7	437.8	54.110	0.05568	0.1219	7.0107
270.9	166.9	437.8	54.209	0.06830	0.1220	7.0135
270.7	167.0	437.7	54.295	0.08094	0.1220	7.0161
270.6	167.0	437.6	54.353	0.09357	0.1220	7.0182
270.5	167.2	437.7	54.389	0.10619	0.1220	7.0189
270.4	167.6	438.0	54.331	0.11864	0.1219	7.0153
270.9	167.5	438.4	53.908	0.13016	0.1219	7.0000
298.7	146.1	444.9	51.245	0.12258	0.1184	6.5832
311.4	161.5	472.9	57 273	0.11873	0.1115	5.9740

STAGE END PRESSURE DROPS, PSF					TOTAL	REYNOLDS NUMBERS		
CONTRACTION		ENLARGEMENT			PRESSURE	ENTRANCE	CENTER	EXIT
FRICTION	MOMENTUM	FRICTION	MOMENTUM	TOTAL	DROP,PSF			
126.1	295.1	45.3	-325.0	141.4	630.5	19370.	18924.	18404.
168.8	395.0	60.4	-433.2	191.0	628.9	32405.	31695.	30845.
168.8	395.0	60.4	-433.2	191.0	628.8	32433.	31727.	30873.
168.8	395.2	60.4	-433 4	191.1	628.8	32561.	31854.	30999.
168.9	395.3	60.4	-433.5	191.1	628.8	32670.	31963.	31107.
169.0	395.4	60.4	-433.6	191.2	628.8	32746.	32039.	31183.
169.0	395.4	60.5	-433.7	191.1	628.8	32792.	32084.	31227.
168.8	395.1	60.4	-433.5	190.9	628.9	32729.	32018.	31159.
168.4	394.2	60.3	-432.5	190.4	628.8	32200.	31488.	30635.
159.5	373.3	56.7	-406.8	182.7	627.6	26855.	26302.	25631.
142.2	332.8	51.5	-369.2	157.3	630.2	30192.	29449.	28612.

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INPUT DATA. STAGE NO. 10
STAGE POWER= 765.6 BTU/SEC
NUMBER OF RINGS=10
NUMBER OF SHIELDS= 1
STAGE LENGTH= 0.1250 FT.
ENTRANCE PRESSURE= 101403.3 PSF
HEAT LOSS= 0.8289 BTU/SEC

PASSAGE RADII,FT INNER	OUTER	F AREA,SQIN	S AREA,SQIN	RNG PWR DIST	EFF	DIAM,IN	PWR DENSITY BTU/SEC SQIN	EMISSIVITY
0.01642	0.01983	0.055921	1.857057	0.00060		0.0818	0.2473	0.2300
0.02158	0.02683	0.114976	4.683357	0.04000		0.1260	6.5386	0.2600
0.02858	0.03383	0.148226	6.266718	0.05320		0.1260	6.4991	0.2600
0.03558	0.04083	0.181477	7.850079	0.06640		0.1260	6.4755	0.2600
0.04258	0.04783	0.214728	9.433441	0.07960		0.1260	6.4599	0.2600
0.04958	0.05483	0.247978	11.016802	0.09280		0.1260	6.4487	0.2600
0.05658	0.06183	0.281229	12.600163	0.10604		0.1260	6.4428	0.2600
0.06358	0.06883	0.314479	14.183525	0.11925		0.1260	6.4366	0.2600
0.07058	0.07583	0.347730	15.766886	0.13250		0.1260	6.4335	0.2600
0.07758	0.08233	0.343622	17.350247	0.14567		0.1140	6.4275	0.2600
0.08408	0.08792	0.298794	18.820511	0.15794		0.0922	6.4245	0.2600
0.08917	0.09917		9.943509	0.00600			0.4619	0.2300
								0.0500

PLATE TEMPERATURES FOR ALL INCREMENTS, DEGREES R

INCREMENT NO.	1	2	3	4	5	6	7	8	9	10
1	2833.9	2879.6	2910.1	2936.5	2961.3	2986.4	3008.7	3031.0	3053.7	3075.8
2	3801.1	4218.0	4361.5	4441.9	4497.4	4548.6	4578.9	4606.5	4641.1	4561.1
3	3771.5	4211.3	4369.8	4458.7	4519.5	4566.2	4604.8	4638.5	4685.3	4704.7
4	3761.9	4199.8	4357.8	4446.6	4507.5	4554.1	4592.8	4626.5	4673.5	4692.8
5	3750.1	4186.6	4344.1	4432.6	4493.5	4540.1	4578.7	4612.4	4659.2	4678.3
6	3741.1	4176.5	4333.6	4422.0	4482.7	4529.4	4567.9	4601.5	4648.3	4667.2
7	3735.5	4170.3	4327.2	4415.5	4476.2	4523.0	4561.4	4595.0	4641.7	4660.6
8	3735.9	4170.6	4327.6	4415.9	4476.6	4523.4	4561.9	4595.5	4642.3	4661.3
9	3760.5	4196.5	4353.9	4442.2	4502.8	4549.5	4588.2	4621.9	4668.9	4688.3
10	3858.5	4285.8	4437.3	4522.1	4580.3	4625.3	4663.1	4695.9	4737.8	4756.8
11	3566.1	3957.6	4091.1	4165.5	4216.9	4257.1	4298.6	4321.9	4347.0	4364.9
12	2285.8	2333.2	2361.2	2384.5	2405.8	2426.3	2447.1	2465.7	2484.4	2502.9
13	716.1	716.3	716.5	716.7	716.9	717.1	717.3	717.5	717.7	717.9
AV FUEL TEMP	3697.0	4121.4	4272.7	4357.6	4415.9	4461.3	4499.7	4531.2	4573.1	4592.0
AV GAS TEMP	2846.4	2867.1	2887.7	2908.2	2928.8	2949.3	2969.7	2990.2	3010.6	3031.0
DIFF IN TEMP	850.5	1254.4	1385.0	1449.4	1487.2	1512.1	1530.0	1541.0	1562.5	1561.0

STAGE AVERAGE FUEL TEMP = 4352.2 DEG R
STAGE AVERAGE OUTLET GAS TEMP = 3051.5 DEG R
STAGE AVERAGE OUTLET DYNAMIC HEAD = 7.3387 PSI

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COMPUTED TEMPERATURES AND PRESSURES. STAGE NO. 10

	PLATE TEMPERATURES ENTRANCE	CENTER	EXIT	GAS TEMPERATURES ENTRANCE	CENTER	EXIT
CENTER PLUG	2834.	2961.	3076.	2787.	2893.	3000.
FUEL RINGS	3801.	4497.	4661.	2928.	3033.	3136.
	3771.	4519.	4705.	2926.	3031.	3135.
	3762.	4507.	4693.	2916.	3021.	3125.
	3750.	4494.	4678.	2908.	3012.	3116.
	3741.	4483.	4667.	2902.	3007.	3110.
	3736.	4476.	4661.	2899.	3003.	3107.
	3736.	4477.	4661.	2904.	3009.	3113.
	3761.	4503.	4688.	2944.	3050.	3155.
	3858.	4580.	4757.	3057.	3155.	3256.
	3566.	4217.	4365.	2227.	2323.	2415.
RADTN SHIELDS	2286.	2406.	2503.			
CONTAINMNT SHELL	716.	717.	718.			

PASSAGE PRESSURE DROPS, PSF FRICTION	MOMENTUM	TOTAL	MASS FLOW RATE LB/SEC-FT**2	PASSAGE WT FLOW, LB/SEC	EXIT MACH NO.	EXIT DYNAMIC HEAD, PSI
395.1	122.5	517.6	47.749	0.01853	0.1098	5.6304
305.5	153.7	459.2	54.148	0.04320	0.1276	7.5796
305.3	153.9	459.2	54.162	0.05572	0.1276	7.5797
305.1	154.1	459.1	54.260	0.06835	0.1276	7.5827
304.9	154.1	459.1	54.347	0.08100	0.1276	7.5856
304.8	154.2	459.0	54.407	0.09364	0.1276	7.5876
304.7	154.4	459.1	54.437	0.10627	0.1276	7.5882
304.5	154.9	459.4	54.368	0.11870	0.1276	7.5840
305.4	154.2	459.6	53.952	0.13023	0.1275	7.5691
334.6	132.9	467.5	51.485	0.12324	0.1238	7.1109
348.4	151.3	499.6	56 758	0.11771	0.1162	6.4066

STAGE END PRESSURE DROPS, PSF CONTRACTION FRICTION	MOMENTUM	ENLARGEMENT FRICTION	MOMENTUM	TOTAL	TOTAL PRESSURE DROP, PSF	REYNOLDS NUMBERS ENTRANCE	CENTER	EXIT
136.8	320.1	48.5	-348.0	157.4	675.0	18189.	17828.	17389.
184.8	432.5	65.3	-468.3	214.3	673.4	30718.	30129.	29451.
184.8	432.4	65.3	-468.3	214.2	673.4	30738.	30152.	29479.
184.8	432.6	65.3	-468.5	214.2	673.4	30863.	30272.	29586.
184.9	432.7	65.3	-468.7	214.3	673.4	30971.	30379.	29689.
185.0	432.9	65.3	-468.8	214.4	673.4	31046.	30453.	29761.
184.9	432.9	65.4	-468.8	214.3	673.4	31088.	30493.	29799.
184.8	432.5	65.3	-468.6	214.0	673.4	31012.	30416.	29722.
184.5	431.7	65.2	-467.6	213.7	673.3	30491.	29906.	29231.
174.5	408.3	61.2	-439.3	204.7	672.2	25660.	25232.	24711.
154.4	361.4	55.2	-395.9	175.2	674.8	28188.	27557.	26851.

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INPUT DATA, STAGE NO. 11
STAGE POWER= 700.2 BTU/SEC
NUMBER OF RINGS=10
NUMBER OF SHIELDS= 1
STAGE LENGTH= 0.1250 FT.
ENTRANCE PRESSURE= 100729.8 PSF
HEAT LOSS= 0.9532 BTU/SEC

PASSAGE RADII,FT INNER	OUTER	F AREA,SQIN	S AREA,SQIN	RNG PWR DIST	EFF DIA,IN	PWR DENSITY BTU/SEC/SQIN	EMISSIVITY
0.01642	0.01983	0.055921	1.857057	0.00060	0.0818	0.2262	0.2300
0.02158	0.02683	0.114976	4.683357	0.04000	0.1260	5.9807	0.2600
0.02858	0.03383	0.148226	6.266718	0.05320	0.1260	5.9446	0.2600
0.03558	0.04083	0.181477	7.850079	0.06640	0.1260	5.9230	0.2600
0.04258	0.04783	0.214728	9.433441	0.07960	0.1260	5.9087	0.2600
0.04958	0.05483	0.247978	11.016802	0.09280	0.1260	5.8985	0.2600
0.05658	0.06183	0.281229	12.600163	0.10604	0.1260	5.8931	0.2600
0.06358	0.06883	0.314479	14.183525	0.11925	0.1260	5.8874	0.2600
0.07058	0.07583	0.347730	15.766886	0.13250	0.1260	5.8846	0.2600
0.07758	0.08233	0.343622	17.350247	0.14567	0.1140	5.8792	0.2600
0.08408	0.08792	0.298794	18.820511	0.15794	0.0922	5.8764	0.2600
0.08917	0.09917		9.943509	0.00600		0.4225	0.2300
							0.0500

PLATE TEMPERATURES FOR ALL INCREMENTS, DEGREES R

INCREMENT NO. M	1	2	3	4	5	6	7	8	9	10
1	3044.4	3086.6	3114.4	3138.4	3160.9	3183.7	3203.9	3224.2	3244.8	3264.9
2	3915.2	4284.4	4411.2	4482.4	4531.8	4577.2	4604.6	4629.5	4660.7	4678.8
3	3891.6	4280.9	4421.0	4499.9	4553.9	4595.7	4630.4	4660.6	4702.5	4719.9
4	3882.5	4270.1	4409.8	4488.6	4542.8	4584.4	4619.2	4649.5	4691.6	4709.0
5	3870.6	4256.9	4396.2	4474.8	4528.9	4570.6	4605.3	4635.5	4677.5	4695.0
6	3861.3	4246.8	4385.7	4464.1	4518.1	4559.9	4594.5	4624.7	4666.6	4684.0
7	3855.7	4240.7	4379.5	4457.8	4511.8	4553.7	4588.2	4618.4	4660.3	4677.5
8	3857.0	4241.9	4380.8	4459.1	4513.2	4555.1	4589.7	4619.9	4661.8	4679.2
9	3883.3	4269.1	4408.2	4486.5	4540.4	4582.1	4616.8	4647.1	4689.0	4706.4
10	3968.5	4345.7	4479.3	4553.9	4605.2	4645.0	4678.4	4707.4	4744.5	4761.3
11	3659.6	4004.2	4121.8	4187.5	4233.0	4268.7	4305.9	4326.9	4349.7	4366.3
12	2467.0	2510.2	2535.9	2557.4	2577.1	2596.0	2615.3	2632.6	2650.0	2667.2
13	718.1	718.3	718.5	718.7	718.9	719.1	719.3	719.5	719.7	719.9
AV FUEL TEMP	3812.1	4187.5	4321.2	4396.4	4448.2	4488.7	4523.2	4551.4	4589.0	4606.2
AV GAS TEMP	3051.5	3070.1	3088.7	3107.2	3125.7	3144.2	3162.7	3181.2	3199.6	3218.0
DIFF IN TEMP	760.7	1117.4	1232.5	1289.1	1322.5	1344.5	1360.5	1370.3	1389.4	1388.2

STAGE AVERAGE FUEL TEMP = 4392.4 DEG R
STAGE AVERAGE OUTLET GAS TEMP = 3236.3 DEG R
STAGE AVERAGE OUTLET DYNAMIC HEAD = 7.8463 PSI

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COMPUTED TEMPERATURES AND PRESSURES. STAGE NO. 11

	PLATE TEMPERATURES			GAS TEMPERATURES		
	ENTRANCE	CENTER	EXIT	ENTRANCE	CENTER	EXIT
CENTER PLUG	3044.	3161.	3265.	3000.	3096.	3194.
FUEL RINGS	3915.	4532.	4679.	3136.	3231.	3324.
	3892.	4554.	4720.	3135.	3229.	3323.
	3882.	4543.	4709.	3125.	3219.	3313.
	3871.	4529.	4695.	3116.	3210.	3304.
	3861.	4518.	4684.	3110.	3204.	3297.
	3856.	4512.	4678.	3107.	3201.	3294.
	3857.	4513.	4679.	3113.	3208.	3302.
	3883.	4540.	4706.	3156.	3251.	3345.
	3969.	4605.	4761.	3249.	3334.	3423.
	3660.	4233.	4366.	2415.	2504.	2590.
RADTN SHIELDS	2467.	2577.	2667.			
CONTAINMNT SHELL	718.	719.	720.			

PASSAGE PRESSURE DROPS, PSF			MASS FLOW RATE			
FRICTION	MOMENTUM	TOTAL	LB/SEC-FT**2	PASSAGE WT FLOW, LB/SEC	EXIT MACH NO.	EXIT DYNAMIC HEAD, PSI
431.1	112.6	543.7	47.443	0.01842	0.1136	5.9621
337.9	141.8	479.7	54.199	0.04327	0.1327	8.1100
337.7	142.0	479.7	54.209	0.05580	0.1327	8.1103
337.4	142.3	479.7	54.304	0.06843	0.1328	8.1133
337.3	142.4	479.6	54.389	0.08110	0.1328	8.1164
337.1	142.4	479.6	54.449	0.09376	0.1328	8.1185
337.0	142.6	479.6	54.475	0.10639	0.1328	8.1186
336.9	143.1	479.9	54.396	0.11879	0.1327	8.1136
338.1	141.8	479.9	54.001	0.13040	0.1327	8.1013
368.8	121.1	489.9	51.772	0.12355	0.1288	7.6168
382.8	141.2	524.0	56.227	0.11667	0.1204	6.7939

STAGE END PRESSURE DROPS, PSF					TOTAL	REYNOLDS NUMBERS		
CONTRACTION		ENLARGEMENT			PRESSURE	ENTRANCE	CENTER	EXIT
FRICTION	MOMENTUM	FRICTION	MOMENTUM	TOTAL	DROP, PSF			
146.3	342.5	51.4	-368.4	171.7	715.4	17192.	16902.	16554.
199.6	467.2	69.8	-501.0	235.8	715.4	29353.	28890.	28353.
199.6	467.2	69.8	-501.0	235.7	715.4	29365.	28905.	28364.
199.7	467.4	69.9	-501.2	235.7	715.4	29480.	29015.	28472.
199.8	467.5	69.9	-501.4	235.8	715.4	29581.	29115.	28569.
199.8	467.6	69.9	-501.5	235.9	715.4	29652.	29185.	28637.
199.8	467.6	69.9	-501.5	235.8	715.4	29687.	29219.	28669.
199.6	467.2	69.9	-501.2	235.5	715.4	29603.	29134.	28584.
199.4	466.7	69.8	-500.4	235.5	715.4	29126.	28668.	28136.
188.7	441.6	65.6	-470.5	225.4	715.3	24785.	24452.	24039.
165.5	387.2	58.5	-419.8	191.4	715.3	25469.	25976.	25389.

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INPUT DATA, STAGE NO. 12
STAGE POWER= 638.0 BTU/SEC
NUMBER OF RINGS=10
NUMBER OF SHIELDS= 1
STAGE LENGTH= 0.1250 FT.
ENTRANCE PRESSURE= 100014.4 PSF
HEAT LOSS= 1.0754 BTU/SEC

PASSAGE RADII,FT INNER	OUTER	F AREA,SQIN	S AREA,SQIN	RNG PWR DIST	EFF DIAM,IN	PWR DENSITY BTU/SEC SQIN	EMISSIVITY
0.01642	0.01983	0.055921	1.857057	0.00060	0.0818	0.2061	0.2300
0.02158	0.02683	0.114976	4.683357	0.04000	0.1260	5.4488	0.2600
0.02858	0.03383	0.148226	6.266718	0.05320	0.1260	5.4159	0.2600
0.03558	0.04083	0.181477	7.850079	0.06640	0.1260	5.3963	0.2600
0.04258	0.04783	0.214728	9.433441	0.07960	0.1260	5.3832	0.2600
0.04958	0.05483	0.247978	11.016802	0.09280	0.1260	5.3739	0.2600
0.05658	0.06183	0.281229	12.600163	0.10604	0.1260	5.3690	0.2600
0.06358	0.06883	0.314479	14.183525	0.11925	0.1260	5.3638	0.2600
0.07058	0.07583	0.347730	15.766886	0.13250	0.1260	5.3613	0.2600
0.07758	0.08233	0.343622	17.350247	0.14567	0.1140	5.3563	0.2600
0.08408	0.08792	0.298794	18.820511	0.15794	0.0922	5.3538	0.2600
0.08917	0.09917		9.943509	0.00600		0.3850	0.2300
							0.0500

PLATE TEMPERATURES FOR ALL INCREMENTS, DEGREES R

INCREMENT NO. M	1	2	3	4	5	6	7	8	9	10
1	3235.5	3274.3	3299.5	3321.2	3341.5	3362.1	3380.3	3399.5	3417.1	3435.1
2	4017.0	4343.3	4455.3	4518.2	4562.0	4602.5	4626.6	4648.7	4676.1	4692.2
3	3999.5	4343.6	4467.1	4536.5	4584.3	4621.3	4651.9	4678.5	4715.4	4730.8
4	3990.9	4333.7	4456.8	4526.1	4573.9	4611.0	4641.6	4668.4	4705.4	4720.8
5	3979.0	4320.8	4443.6	4512.7	4560.4	4597.5	4628.2	4654.9	4691.9	4707.3
6	3969.7	4310.7	4433.3	4502.3	4549.9	4586.8	4617.7	4644.3	4681.2	4696.6
7	3964.2	4304.9	4427.3	4496.2	4543.8	4580.7	4611.6	4638.3	4675.2	4690.6
8	3966.2	4306.9	4429.3	4498.3	4545.9	4582.9	4613.8	4640.5	4677.4	4692.9
9	3993.0	4334.1	4456.7	4525.7	4573.1	4609.9	4640.6	4667.2	4704.1	4719.5
10	4065.1	4397.8	4515.1	4580.7	4625.7	4660.6	4689.7	4714.9	4747.2	4761.9
11	3744.8	4048.5	4152.3	4210.6	4251.2	4283.2	4316.3	4334.8	4354.7	4369.6
12	2635.7	2675.0	2698.5	2718.2	2736.4	2753.8	2771.5	2787.4	2803.4	2819.2
13	720.1	720.3	720.5	720.7	720.9	721.1	721.3	721.5	721.7	721.9
AV FUEL TEMP	3915.8	4247.6	4365.4	4431.7	4477.5	4513.4	4544.0	4568.9	4601.9	4617.1
AV GAS TEMP	3236.3	3253.0	3269.7	3286.4	3303.0	3319.6	3336.2	3352.7	3369.2	3385.7
DIFF IN TEMP	679.5	994.5	1095.7	1145.4	1174.5	1193.8	1207.8	1216.1	1232.7	1231.4

STAGE AVERAGE FUEL TEMP = 4428.3 DEG R
STAGE AVERAGE OUTLET GAS TEMP = 3402.3 DEG R
STAGE AVERAGE OUTLET DYNAMIC HEAD = 8.3174 PSI

COMPUTED TEMPERATURES AND PRESSURES, STAGE NO. 12

	PLATE TEMPERATURES			GAS TEMPERATURES		
	ENTRANCE	CENTER	EXIT	ENTRANCE	CENTER	EXIT
CENTER PLUG	3735.	3342.	3435.	3194.	3282.	3370.
FUEL RINGS	4017.	4562.	4692.	3324.	3409.	3492.
	3999.	4584.	4731.	3323.	3408.	3492.
	3991.	4574.	4721.	3313.	3397.	3481.
	3979.	4560.	4707.	3304.	3388.	3472.
	3970.	4550.	4697.	3297.	3382.	3465.
	3964.	4544.	4691.	3294.	3379.	3462.
	3966.	4546.	4693.	3302.	3387.	3471.
	3993.	4573.	4719.	3345.	3430.	3514.
	4065.	4626.	4762.	3418.	3492.	3570.
	3745.	4251.	4370.	2590.	2673.	2753.
RADTN SHIELDS	2636.	2736.	2819.			
CONTAINMNT SHELL	720.	721.	722.			

PASSAGE PRESSURE DROPS, PSF			MASS FLOW RATE			
FRICTION	MOMENTUM	TOTAL	LB/SEC-FT**2	PASSAGE WT FLOW, LB/SEC	EXIT MACH NO.	EXIT DYNAMIC HEAD, PSI
466.5	103.8	570.3	47.279	0.01834	0.1175	6.2963
368.4	130.4	498.8	54.240	0.04332	0.1375	8.6014
368.2	130.6	498.9	54.243	0.05585	0.1375	8.6014
367.9	130.9	498.8	54.336	0.06849	0.1375	8.6046
367.7	131.0	498.8	54.421	0.08117	0.1375	8.6078
367.6	131.1	498.7	54.480	0.09384	0.1375	8.6101
367.4	131.4	498.8	54.504	0.10647	0.1375	8.6103
367.4	131.7	499.1	54.420	0.11887	0.1375	8.6053
368.9	130.0	498.9	54.044	0.13055	0.1375	8.5925
399.8	110.1	509.8	51.948	0.12396	0.1333	8.0623
416.8	132.0	548.7	55.854	0.11573	0.1245	7.1811

STAGE END PRESSURE DROPS, PSF					TOTAL	REYNOLDS NUMBERS		
CONTRACTION		ENLARGEMENT			PRESSURE	ENTRANCE	CENTER	EXIT
FRICTION	MOMENTUM	FRICTION	MOMENTUM	TOTAL	DROP, PSF			
155.8	364.7	54.2	-389.0	185.8	756.1	16429.	16199.	15920.
213.4	499.5	74.1	-531.3	255.7	754.5	28273.	27905.	27466.
213.4	499.5	74.1	-531.3	255.7	754.5	28279.	27913.	27471.
213.5	499.6	74.1	-531.5	255.7	754.5	28385.	28016.	27573.
213.5	499.8	74.1	-531.7	255.8	754.5	28480.	28111.	27665.
213.6	499.9	74.1	-531.8	255.8	754.5	28546.	28176.	27730.
213.6	499.9	74.1	-531.8	255.8	754.6	28577.	28205.	27757.
213.4	499.5	74.1	-531.5	255.5	754.6	28490.	28117.	27670.
213.3	499.1	74.0	-530.8	255.6	754.5	28056.	27691.	27255.
201.3	471.1	69.4	-498.0	243.8	753.6	24064.	23795.	23446.
176.4	412.8	61.8	-443.7	207.3	756.0	25106.	24703.	24243.

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INPUT DATA, STAGE NO. 13
STAGE POWER= 574.2 BTU/SEC
NUMBER OF RINGS=10
NUMBER OF SHIELDS= 1
STAGE LENGTH= 0.1250 FT.
ENTRANCE PRESSURE= 99259.6 PSF
HEAT LOSS= 1.1947 BTU/SEC

PASSAGE RADII,FT INNER	OUTER	F AREA,SQIN	S AREA,SQIN	RNG PWR DIST	EFF DIAM,IN	PWR DENSITY BTU/SEC SQIN	EMISSIVITY
0.01642	0.01983	0.055921	1.857057	0.00060	0.0818	0.1855	0.2300
0.02158	0.02683	0.114976	4.583357	0.04000	0.1260	4.9039	0.2600
0.02858	0.03383	0.148226	6.266718	0.05320	0.1260	4.8743	0.2600
0.03558	0.04083	0.181477	7.850079	0.06640	0.1260	4.8566	0.2600
0.04258	0.04783	0.214728	9.433441	0.07960	0.1260	4.8449	0.2600
0.04958	0.05483	0.247979	11.016802	0.09280	0.1260	4.8365	0.2600
0.05658	0.06183	0.281229	12.600163	0.10604	0.1260	4.8321	0.2600
0.06358	0.06883	0.314479	14.183525	0.11925	0.1260	4.8274	0.2600
0.07058	0.07583	0.347730	15.766886	0.13250	0.1260	4.8252	0.2600
0.07758	0.08233	0.343622	17.350247	0.14567	0.1140	4.8207	0.2600
0.08408	0.08792	0.298794	18.820511	0.15794	0.0922	4.8184	0.2600
0.08917	0.09917		9.943509	0.00600		0.3465	0.2300
							0.0500

PLATE TEMPERATURES FOR ALL INCREMENTS, DEGREES R

INCREMENT NO. M	1	2	3	4	5	6	7	8	9	10
1	3407.6	3442.6	3465.1	3484.4	3502.4	3520.7	3536.9	3553.0	3569.4	3585.4
2	4101.0	4386.1	4483.8	4538.4	4576.5	4611.7	4632.8	4652.1	4675.5	4688.9
3	4088.5	4389.1	4496.4	4556.5	4597.8	4629.9	4656.5	4679.9	4710.9	4723.3
4	4080.5	4380.0	4487.2	4547.1	4588.5	4620.5	4647.2	4670.6	4702.3	4714.7
5	4068.7	4367.5	4474.5	4534.3	4575.6	4607.6	4634.2	4657.6	4689.7	4702.5
6	4059.4	4357 6	4464 5	4524.3	4565.4	4597.4	4623.9	4647.3	4679.4	4692.8
7	4054.0	4352.0	4458.8	4518.6	4559.7	4591.7	4618.2	4641.6	4673.7	4687.3
8	4056.7	4354.6	4461.5	4521.3	4562.4	4594.4	4621.0	4644.4	4676.5	4689.9
9	4083 4	4381.2	4487.8	4547.5	4588.6	4620.5	4646.8	4669.5	4700.9	4713.6
10	4141.8	4431.4	4533.1	4589.7	4628.2	4657.9	4682.5	4703.5	4730.3	4742.2
11	3816.6	4081.2	4171.7	4222.4	4257.8	4285.7	4314.8	4331.1	4348.5	4361.8
12	2791.5	2826.6	2847.7	2865.6	2882.1	2898.0	2914.0	2928.6	2943.2	2957.7
13	722.0	722.1	722.2	722.3	722.4	722.5	722.6	722.7	722.8	722.9
AV FUEL TEMP	4001.8	4291.5	4394.1	4451.6	4491.2	4522.3	4548.7	4570.3	4598.7	4611.7
AV GAS TEMP	3402.3	3417.2	3432.0	3446.7	3461.5	3476.2	3490.9	3505.6	3520.3	3535.0
DIFF IN TEMP	599.4	874.3	962.2	1004.9	1029.7	1046.1	1057.7	1064.7	1078.4	1076.7

STAGE AVERAGE FUEL TEMP = 4448.2 DEG R
STAGE AVERAGE OUTLET GAS TEMP = 3549.7 DEG R
STAGE AVERAGE OUTLET DYNAMIC HEAD = 8.7538 PSI

COMPUTED TEMPERATURES AND PRESSURES, STAGE NO. 13

	PLATE TEMPERATURES			GAS TEMPERATURES		
	ENTRANCE	CENTER	EXIT	ENTRANCE	CENTER	EXIT
CENTER PLUG	3408.	3502.	3585.	3370.	3448.	3527.
FUEL RINGS	4101.	4576.	4689.	3492.	3567.	3641.
	4089.	4598.	4723.	3492.	3567.	3642.
	4086.	4588.	4715.	3481.	3556.	3631.
	4069.	4576.	4702.	3472.	3547.	3621.
	4059.	4565.	4693.	3465.	3540.	3614.
	4054.	4560.	4687.	3462.	3537.	3611.
	4057.	4562.	4690.	3471.	3546.	3621.
	4083.	4589.	4714.	3514.	3589.	3664.
	4142.	4628.	4742.	3566.	3630.	3698.
	3817.	4258.	4362.	2753.	2829.	2902.
RADTN SHIELDS	2792.	2882.	2958.			
CONTAINMNT SHELL	722.	722.	723.			

PASSAGE PRESSURE DROPS,PSF			MASS FLOW RATE			
FRICTION	MOMENTUM	TOTAL	LB/SEC-FT**2	PASSAGE WT FLOW,LB/SEC	EXIT MACH NO.	EXIT DYNAMIC HEAD,PSI
499.2	94.8	593.9	47.110	0.01827	0.1209	6.5956
397.4	119.2	516.5	54.278	0.04335	0.1419	9.0570
397.2	119.4	516.6	54.277	0.05588	0.1419	9.0567
396.9	119.7	516.6	54.368	0.06853	0.1420	9.0603
396.7	119.8	516.5	54.453	0.08121	0.1420	9.0640
396.5	119.9	516.4	54.512	0.09389	0.1420	9.0666
396.4	120.1	516.5	54.533	0.10652	0.1420	9.0668
396.4	120.4	516.8	54.444	0.11892	0.1419	9.0613
398.1	118.4	516.4	54.091	0.13065	0.1419	9.0493
429.4	99.5	528.9	52.145	0.12445	0.1375	8.4862
448.2	122.4	570.6	55.452	0.11493	0.1281	7.5233

STAGE END PRESSURE DROPS, PSF					TOTAL	REYNOLDS NUMBERS		
CONTRACTION		ENLARGEMENT			PRESSURE	ENTRANCE	CENTER	EXIT
FRICTION	MOMENTUM	FRICTION	MOMENTUM	TOTAL	DROP,PSF			
164.5	384.9	56.8	-407.5	198.7	792.6	15809.	15623.	15393.
226.3	529.5	78.0	-559.3	274.4	791.0	27400.	27087.	26724.
226.2	529.5	78.0	-559.3	274.3	791.0	27401.	27089.	26724.
226.3	529.6	78.0	-559.5	274.4	791.0	27502.	27190.	26817.
226.4	529.8	78.0	-559.8	274.5	791.0	27595.	27283.	26904.
226.4	530.0	78.1	-559.9	274.5	791.0	27659.	27347.	26964.
226.4	529.9	78.1	-559.9	274.5	791.0	27685.	27373.	26989.
226.3	529.5	78.0	-559.6	274.2	791.0	27594.	27280.	26899.
226.1	529.2	77.9	-558.9	274.4	790.9	27191.	26881.	26533.
213.2	499.0	73.1	-524.1	261.2	790.1	23485.	23267.	23003.
186.1	435.6	64.8	-464.8	221.8	792.3	23978.	23631.	23228.

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INPUT DATA, STAGE NO. 14
STAGE POWER= 516.5 BTU/SEC
NUMBER OF RINGS=10
NUMBER OF SHIELDS= 1
STAGE LENGTH= 0.1250 FT.
ENTRANCE PRESSURE= 98468.5 PSF
HEAT LOSS= 11.3090 BTU/SEC

PASSAGE RADII,FT INNER	OUTER	F AREA,SQIN	S AREA,SQIN	RNG PWR DIST	EFF DIAM,IN	PWR DENSITY BTU/SEC/SQIN	EMISSIVITY
0.01642	0.01983	0.055921	1.857057	0.00060	0.0818	0.1669	0.2300
0.02158	0.02683	0.114976	4.683357	0.04000	0.1260	4.4109	0.2600
0.02858	0.03383	0.148226	6.266718	0.05320	0.1260	4.3843	0.2600
0.03558	0.04083	0.181477	7.850079	0.06640	0.1260	4.3684	0.2600
0.04258	0.04783	0.214728	9.433441	0.07960	0.1260	4.3578	0.2600
0.04958	0.05483	0.247978	11.016802	0.09280	0.1260	4.3503	0.2600
0.05658	0.06183	0.281229	12.600163	0.10604	0.1260	4.3463	0.2600
0.06358	0.06883	0.314479	14.183525	0.11925	0.1260	4.3421	0.2600
0.07058	0.07583	0.347730	15.766886	0.13250	0.1260	4.3401	0.2600
0.07758	0.08233	0.343622	17.350247	0.14567	0.1140	4.3360	0.2600
0.08408	0.08792	0.298794	18.820511	0.15794	0.0922	4.3340	0.2600
0.08917	0.09917		9.943509	0.00600		0.3116	0.2300
							0.0500

PLATE TEMPERATURES FOR ALL INCREMENTS, DEGREES R

INCREMENT NO. M	1	2	3	4	5	6	7	8	9	10
1	3560.8	3592.1	3612.2	3629.3	3645.2	3661.4	3675.7	3689.9	3704.3	3718.5
2	4174.4	4422.6	4507.3	4554.5	4587.4	4617.6	4635.4	4651.5	4671.5	4683.0
3	4165.2	4426.3	4519.1	4570.6	4605.9	4633.1	4655.5	4675.1	4702.2	4713.4
4	4157.9	4418.2	4510.8	4562.3	4597.6	4624.7	4647.3	4666.9	4694.1	4705.4
5	4146.7	4406.5	4499.0	4550.4	4585.6	4612.7	4635.3	4655.0	4682.1	4593.4
6	4137.7	4397.2	4489.5	4540.9	4576.1	4603.2	4625.8	4645.4	4672.6	4683.8
7	4132.7	4392.1	4484.4	4535.7	4570.9	4598.0	4620.6	4640.3	4667.4	4678.6
8	4135.8	4395.1	4487.4	4538.7	4573.9	4601.0	4623.7	4643.4	4670.5	4681.8
9	4161.1	4419.7	4511.6	4562.8	4597.8	4624.7	4647.2	4666.8	4693.7	4704.9
10	4205.6	4456.1	4543.6	4592.0	4625.1	4650.5	4671.8	4690.3	4713.8	4724.5
11	3882.3	4112.9	4191.9	4236.3	4267.5	4292.0	4317.8	4332.3	4347.5	4359.4
12	2934.5	2965.7	2984.8	3000.9	3015.9	3030.3	3044.9	3058.1	3071.4	3084.6
13	723.0	723.1	723.2	723.3	723.4	723.5	723.6	723.7	723.8	723.9
AV FUEL TEMP	4076.9	4328.7	4417.5	4467.0	4501.1	4527.6	4550.3	4568.8	4593.2	4604.5
AV GAS TEMP	3549.7	3562.9	3576.0	3589.1	3602.2	3615.3	3628.4	3641.4	3654.4	3667.4
DIFF IN TEMP	527.2	765.9	841.5	877.9	898.9	912.3	921.9	927.4	938.8	937.1

STAGE AVERAGE FUEL TEMP = 4463.6 DEG R
STAGE AVERAGE OUTLET GAS TEMP = 3680.5 DEG R
STAGE AVERAGE OUTLET DYNAMIC HEAD = 9.1583 PSI

COMPUTED TEMPERATURES AND PRESSURES. STAGE NO. 14

	PLATE TEMPERATURES			GAS TEMPERATURES		
	ENTRANCE	CENTER	EXIT	ENTRANCE	CENTER	EXIT
CENTER PLUG	3561.	3645.	3718.	3527.	3596.	3666.
FUEL RINGS	4174	4587.	4683.	3641.	3708.	3774.
	4165.	4606.	4713.	3642.	3708.	3774.
	4158.	4598.	4705.	3631.	3697.	3763.
	4147.	4586.	4693.	3621.	3687.	3753.
	4138.	4576.	4684.	3614.	3680.	3746.
	4133.	4571.	4679.	3611.	3678.	3744.
	4136.	4574.	4682.	3621.	3688.	3754.
	4161	4598.	4705.	3664.	3730.	3795.
	4206.	4625.	4724.	3694.	3750.	3810.
	3882.	4267.	4359.	2902.	2972.	3038.
RADTN SHIELDS	2935.	3016.	3085.			
CONTAINMNT SHELL	723.	723.	724.			

PASSAGE PRESSURE DROPS, PSF			MASS FLOW RATE			
FRICTION	MOMENTUM	TOTAL	LB/SEC-FT**2	PASSAGE WT FLOW, LB/SEC	EXIT MACH NO.	EXIT DYNAMIC HEAD, PSI
529.6	86.8	616.4	46.967	0.01822	0.1242	6.8748
424.5	109.3	533.7	54.307	0.04337	0.1461	9.4783
424.3	109.5	533.8	54.304	0.05590	0.1461	9.4780
424.0	109.8	533.8	54.393	0.06855	0.1461	9.4819
423.8	109.9	533.7	54.477	0.08124	0.1461	9.4860
423.6	110.0	533.6	54.536	0.09392	0.1461	9.4887
423.4	110.2	533.7	54.554	0.10655	0.1461	9.4890
423.5	110.4	534.0	54.462	0.11895	0.1461	9.4831
425.4	108.1	533.5	54.136	0.13075	0.1461	9.4721
456.9	90.5	547.4	52.328	0.12493	0.1415	8.8792
477.7	113.7	591.4	55.098	0.11421	0.1317	7.8447

STAGE END PRESSURE DROPS, PSF					TOTAL	REYNOLDS NUMBERS		
CONTRACTION		ENLARGEMENT			PRESSURE			
FRICTION	MOMENTUM	FRICTION	MOMENTUM	TOTAL	DROP, PSF	ENTRANCE	CENTER	EXIT
172.5	403.6	59.2	-424.7	210.6	827.0	15300.	15140.	14956.
238.1	557.2	81.6	-585.4	291.5	825.3	26672.	26434.	26140.
238.1	557.1	81.6	-585.3	291.5	825.3	26670.	26433.	26137.
238.1	557.3	81.6	-585.6	291.5	825.3	26762.	26524.	26228.
238.2	557.5	81.7	-585.8	291.6	825.3	26848.	26609.	26313.
238.3	557.7	81.7	-586.0	291.7	825.3	26908.	26669.	26373.
238.3	557.7	81.7	-586.0	291.6	825.3	26930.	26689.	26393.
238.1	557.3	81.6	-585.7	291.3	825.3	26840.	26600.	26302.
238.0	557.1	81.5	-585.0	291.7	825.2	26489.	26254.	25963.
224.3	524.9	76.5	-548.4	277.2	824.5	23047.	22874.	22646.
195.3	457.0	67.6	-484.6	235.2	826.7	23001.	22700.	22361.

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INPUT DATA, STAGE NO. 15
STAGE POWER= 467.8 BTU/SEC
NUMBER OF RINGS=10
NUMBER OF SHIELDS= 1
STAGE LENGTH= 0.1250 FT.
ENTRANCE PRESSURE= 97643.0 PSF
HEAT LOSS= 1.4198 BTU/SEC

PASSAGE RADII,FT INNER	OUTER	F AREA,SQIN	S AREA,SQIN	RNG PWR DIST	EFF DIAM,IN	PWR DENSITY BTU/SEC SQIN	EMISSIVITY
0.01642	0.01983	0.055921	1.857057	0.00060	0.0818	0.1512	0.2300
0.02158	0.02683	0.114976	4.683357	0.04000	0.1260	3.9958	0.2600
0.02858	0.03383	0.148226	6.266718	0.05320	0.1260	3.9717	0.2600
0.03558	0.04083	0.181477	7.850079	0.06640	0.1260	3.9573	0.2600
0.04258	0.04783	0.214728	9.433441	0.07960	0.1260	3.9477	0.2600
0.04958	0.05483	0.247978	11.016802	0.09280	0.1260	3.9409	0.2600
0.05658	0.06183	0.281229	12.600163	0.10604	0.1260	3.9373	0.2600
0.06358	0.06883	0.314479	14.183525	0.11925	0.1260	3.9335	0.2600
0.07058	0.07583	0.347730	15.766886	0.13250	0.1260	3.9316	0.2600
0.07758	0.08233	0.343622	17.350247	0.14567	0.1140	3.9279	0.2600
0.08408	0.08792	0.298794	18.820511	0.15794	0.0922	3.9261	0.2600
0.08917	0.09917		9.943509	0.00600		0.2823	0.2300
							0.0500

PLATE TEMPERATURES FOR ALL INCREMENTS, DEGREES R

INCREMENT NO. M	1	2	3	4	5	6	7	8	9	10
1	3697.1	3725.2	3743.1	3758.4	3772.6	3787.0	3799.8	3812.5	3825.5	3838.2
2	4241.5	4459.0	4533.0	4574.2	4602.8	4629.2	4645.0	4659.5	4677.3	4687.8
3	4235.1	4463.8	4545.0	4590.3	4621.2	4645.4	4665.4	4682.9	4706.8	4717.0
4	4228.2	4456.2	4537.3	4582.6	4613.5	4637.6	4657.7	4675.2	4699.4	4709.6
5	4217.0	4444.6	4525.7	4570.9	4601.9	4625.9	4646.0	4663.5	4687.6	4697.8
6	4208.0	4435.4	4516.3	4561.5	4592.5	4616.5	4636.5	4654.1	4678.1	4688.3
7	4203.1	4430.4	4511.3	4556.4	4587.4	4611.5	4631.6	4649.1	4673.1	4683.3
8	4206.8	4433.9	4514.8	4560.0	4591.0	4615.1	4635.1	4652.7	4676.8	4687.0
9	4231.5	4457.8	4538.3	4583.2	4614.0	4637.9	4657.8	4675.3	4699.1	4709.3
10	4264.3	4483.4	4560.0	4602.4	4631.4	4653.9	4672.8	4689.2	4710.0	4719.6
11	3946.4	4149.3	4218.9	4258.0	4285.4	4307.3	4330.4	4343.3	4357.0	4367.9
12	3065.7	3093.5	3110.7	3125.4	3139.0	3152.2	3165.5	3177.7	3189.8	3201.9
13	724.1	724.3	724.5	724.7	724.9	725.1	725.3	725.5	725.7	725.9
AV FUEL TEMP	4145.8	4366.6	4444.4	4487.9	4517.9	4541.5	4561.6	4578.1	4599.8	4610.1
AV GAS TEMP	3680.5	3692.3	3704.0	3715.7	3727.4	3739.1	3750.8	3762.4	3774.1	3785.7
DIFF IN TEMP	465.3	674.3	740.4	772.2	790.5	802.4	810.9	815.7	825.7	824.4

STAGE AVERAGE FUEL TEMP = 4485.4 DEG R
STAGE AVERAGE OUTLET GAS TEMP = 3797.4 DEG R
STAGE AVERAGE OUTLET DYNAMIC HEAD = 9.5384 PSI

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COMPUTED TEMPERATURES AND PRESSURES. STAGE NO. 15

	PLATE TEMPERATURES			GAS TEMPERATURES		
	ENTRANCE	CENTER	EXIT	ENTRANCE	CENTER	EXIT
CENTER PLUG	3697.	3773.	3838.	3666.	3728.	3791.
FUEL RINGS	4242.	4603.	4688.	3774.	3833.	3892.
	4235.	4621.	4717.	3774.	3833.	3892.
	4228.	4614.	4710.	3763.	3823.	3882.
	4217.	4602.	4698.	3753.	3813.	3871.
	4208.	4592.	4688.	3746.	3806.	3864.
	4203.	4587.	4683.	3744.	3803.	3862.
	4207.	4591.	4687.	3754.	3814.	3873.
	4232.	4614.	4709.	3795.	3854.	3912.
	4264.	4631.	4720.	3806.	3855.	3907.
	3946.	4285.	4368.	3038.	3103.	3164.
RADTN SHIELDS	3066.	3139.	3202.			
CONTAINMNT SHELL	724.	725.	726.			

PASSAGE PRESSURE DROPS, PSF			MASS FLOW RATE			
FRICTION	MOMENTUM	TOTAL	LB/SEC-FT**2	PASSAGE WT FLOW, LB/SEC	EXIT MACH NO.	EXIT DYNAMIC HEAD, PSI
557.8	80.6	638 4	46.842	0.01817	0.1274	7.1362
449.6	101.1	550.7	54.336	0.04339	0.1501	9.8741
449.4	101.3	550.7	54.329	0.05593	0.1501	9.8737
449.1	101.6	550.7	54.415	0.06858	0.1501	9.8775
448.9	101.8	550 6	54.498	0.08127	0.1501	9.8815
448.7	101.9	550.6	54.555	0.09395	0.1501	9.8843
448.5	102.1	550.7	54.571	0.10658	0.1501	9.8844
448.6	102.3	550.9	54.477	0.11898	0.1501	9.8785
450.6	99.6	550.2	54.184	0.13086	0.1501	9.8715
482.2	83.3	565.5	52.499	0.12535	0.1453	9.7508
505.3	106.6	611.9	54.769	0.11354	0.1350	8.1452

STAGE END PRESSURE DROPS, PSF					TOTAL	REYNOLDS NUMBERS		
CONTRACTION		ENLARGEMENT			PRESSURE	ENTRANCE	CENTER	EXIT
FRICTION	MOMENTUM	FRICTION	MOMENTUM	TOTAL	DROP, PSF			
179.8	420.9	61.5	-440.9	221.3	859.7	14881.	14757.	14600.
249.1	582.9	85.0	-609.8	307.2	857 9	26096.	25887.	25635.
249.0	582.9	85.0	-609.8	307.1	857.9	26091.	25883.	25629.
249.1	583.0	85.0	-610.0	307.2	857.9	26180.	25971.	25716.
249.2	583.2	85.1	-610.3	307.3	857.9	26265.	26055.	25799.
249.3	583.4	85.1	-610.4	307.3	857.9	26323.	26113.	25856.
249.2	583.3	85.1	-610.4	307.3	857.9	26342.	26131.	25873.
249.1	583.0	85.0	-610.1	307.0	857.9	26250.	26039.	25781.
249.1	583.0	85.0	-609.5	307.5	857.8	25929.	25726.	25478.
234.5	548.8	79.6	-571.3	291.7	857.2	22688.	22542.	22348.
203.7	476.8	70.1	-503.2	247.5	859.4	22162.	21908.	21625.

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INPUT DATA, STAGE NO. 16
STAGE POWER= 417.7 BTU/SEC
NUMBER OF RINGS=10
NUMBER OF SHIELDS= 1
STAGE LENGTH= 0.1250 FT.
ENTRANCE PRESSURE= 96784.9 PSF
HEAT LOSS= 1.5255 BTU/SEC

PASSAGE RADII,FT	INNER	OUTER	F AREA,SQIN	S AREA,SQIN	RNG PWR DIST	EFF DIAM,IN	PWR DENSITY BTU/SECSQIN	EMISSIVITY
	0.01642	0.01983	0.055921	1.857057	0.00060	0.0818	0.1350	0.2300
	0.02158	0.02683	0.114976	4.683357	0.04000	0.1260	3.5677	0.2600
	0.02858	0.03383	0.148226	6.266718	0.05320	0.1260	3.5461	0.2600
	0.03558	0.04083	0.181477	7.850079	0.06640	0.1260	3.5333	0.2600
	0.04258	0.04783	0.214728	9.433441	0.07960	0.1260	3.5247	0.2600
	0.04958	0.05483	0.247978	11.016802	0.09280	0.1260	3.5186	0.2600
	0.05658	0.06183	0.281229	12.600163	0.10604	0.1260	3.5154	0.2600
	0.06358	0.06883	0.314479	14.183525	0.11925	0.1260	3.5120	0.2600
	0.07058	0.07583	0.347730	15.766886	0.13250	0.1260	3.5104	0.2600
	0.07758	0.08233	0.343622	17.350247	0.14567	0.1140	3.5071	0.2600
	0.08408	0.08792	0.298794	18.820511	0.15794	0.0922	3.5054	0.2600
	0.08917	0.09917		9.943509	0.00600		0.2521	0.2300
								0.0500

PLATE TEMPERATURES FOR ALL INCREMENTS, DEGREES R

INCREMENT NO. M	1	2	3	4	5	6	7	8	9	10
1	3819.0	3843.8	3859.6	3873.1	3885.6	3898.3	3909.6	3920.9	3932.4	3943.5
2	4295.8	4483.8	4547.9	4583.7	4608.7	4631.9	4645.8	4658.6	4674.4	4683.8
3	4293.2	4491.0	4561.3	4600.6	4627.6	4648.7	4666.3	4681.7	4702.7	4711.9
4	4286.7	4484.0	4554.2	4593.5	4620.5	4641.6	4659.3	4674.7	4695.9	4705.0
5	4275.6	4472.6	4542.8	4582.0	4609.1	4630.1	4647.8	4663.2	4684.3	4693.5
6	4266.6	4463.4	4533.5	4572.7	4599.7	4620.8	4638.4	4653.9	4675.0	4684.1
7	4261.8	4458.6	4528.7	4567.9	4595.0	4616.0	4633.6	4649.1	4670.2	4679.4
8	4266.0	4462.6	4532.7	4571.9	4599.0	4620.0	4637.7	4653.2	4674.3	4683.4
9	4289.7	4485.5	4555.1	4594.1	4620.9	4641.8	4659.3	4674.6	4695.5	4704.5
10	4311.1	4500.5	4566.7	4603.5	4628.7	4648.3	4664.8	4679.1	4697.3	4705.8
11	3998.5	4175.1	4235.8	4270.1	4294.1	4313.3	4333.6	4344.9	4356.8	4366.4
12	3185.9	3210.2	3225.6	3238.8	3251.0	3262.9	3274.9	3285.9	3296.9	3307.8
13	726.0	726.1	726.2	726.3	726.4	726.5	726.6	726.7	726.8	726.9
AV FUEL TEMP	4203.0	4394.1	4461.6	4499.5	4525.7	4546.3	4564.0	4578.6	4597.6	4606.8
AV GAS TEMP	3797.4	3807.7	3818.1	3828.4	3838.7	3849.0	3859.3	3869.6	3879.8	3890.1
DIFF IN TEMP	405.6	586.4	643.6	671.1	686.9	697.3	704.7	709.0	717.7	716.7

STAGE AVERAGE FUEL TEMP = 4497.7 DEG R
STAGE AVERAGE OUTLET GAS TEMP = 3900.4 DEG R
STAGE AVERAGE OUTLET DYNAMIC HEAD = 9.8952 PSI

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COMPUTED TEMPERATURES AND PRESSURES. STAGE NO. 16

	PLATE TEMPERATURES			GAS TEMPERATURES		
	ENTRANCE	CENTER	EXIT	ENTRANCE	CENTER	EXIT
CENTER PLUG	3819.	3886	3944.	3791.	3847.	3903.
FUEL RINGS	4296.	4609.	4684.	3892.	3944.	3995.
	4293.	4628.	4712.	3892.	3945.	3996.
	4287.	4621.	4705.	3882.	3934.	3986.
	4276.	4609.	4693.	3871.	3924.	3975.
	4267.	4600.	4684.	3864.	3917.	3968.
	4262.	4595.	4679.	3862.	3914.	3966.
	4266.	4599.	4683.	3873.	3926.	3978.
	4290.	4621.	4705.	3912.	3963.	4013.
	4311.	4629.	4706.	3904.	3946.	3991.
	3999.	4294.	4366.	3164.	3223.	3278.
RADTN SHIELDS	3186.	3251.	3308.			
CONTAINMNT SHELL	726.	726.	727.			

PASSAGE PRESSURE DROPS,PSF			MASS FLOW RATE			
FRICTION	MOMENTUM	TOTAL	LB/SEC-FT**2	PASSAGE WT FLOW,LB/SEC	EXIT MACH NO.	EXIT DYNAMIC HEAD,PSI
584.4	74.2	658.6	46.727	0.01813	0.1304	7.3787
473.3	92.8	566.1	54.363	0.04341	0.1538	10.2468
473.2	93.0	566.2	54.353	0.05595	0.1538	10.2461
472.8	93.3	566.2	54.435	0.06861	0.1538	10.2499
472.6	93.5	566.1	54.517	0.08130	0.1538	10.2541
472.4	93.6	566.0	54.573	0.09398	0.1538	10.2568
472.2	93.9	566.1	54.586	0.10661	0.1538	10.2568
472.4	93.9	566.3	54.491	0.11901	0.1538	10.2509
474.5	91.0	565.5	54.233	0.13098	0.1538	10.2433
506.1	76.0	582.1	52.659	0.12574	0.1488	9.5989
531.3	99.3	630.6	54.459	0.11290	0.1381	8.4246

STAGE END PRESSURE DROPS, PSF					TOTAL	REYNOLDS NUMBERS		
CONTRACTION		ENLARGEMENT			PRESSURE	ENTRANCE	CENTER	EXIT
FRICTION	MOMENTUM	FRICTION	MOMENTUM	TOTAL	DROP,PSF			
186.7	437.0	63.5	-455.8	231.4	890.0	14533.	14425.	14292.
259.4	607.1	88.2	-632.6	322.0	888.1	25598.	25429.	25226.
259.3	607.0	88.2	-632.6	321.9	888.1	25590.	25422.	25217.
259.4	607.1	88.2	-632.8	322.0	888.1	25675.	25503.	25297.
259.5	607.4	88.2	-633.1	322.1	888.1	25757.	25582.	25376.
259.6	607.5	88.3	-633.2	322.1	888.1	25814.	25637.	25430.
259.5	607.4	88.3	-633.2	322.0	888.1	25829.	25651.	25444.
259.4	607.1	88.2	-632.9	321.8	888.1	25737.	25561.	25354.
259.5	607.3	88.2	-632.5	322.5	888.0	25455.	25293.	25093.
244.1	571.4	82.6	-592.7	305.5	887.5	22390.	22275.	22120.
211.6	495.3	72.5	-520.4	259.0	889.7	21448.	21235.	20998.

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INPUT DATA, STAGE NO. 17
STAGE POWER= 375.2 BTU/SEC
NUMBER OF RINGS=10
NUMBER OF SHIELDS= 1
STAGE LENGTH= 0.1250 FT.
ENTRANCE PRESSURE= 95896.5 PSF
HEAT LOSS= 1.6252 BTU/SEC

PASSAGE RADII,FT INNER	OUTER	F AREA,SQIN	S AREA,SQIN	RNG PWR DIST	EFF DIAM,IN	PWR DENSITY BTU/SEC SQIN	EMISSIVITY
0.01642	0.01983	0.055921	1.857057	0.00060	0.0818	0.1212	0.2300
0.02158	0.02683	0.114976	4.583357	0.04000	0.1260	3.2044	0.2600
0.02858	0.03383	0.148226	6.266718	0.05320	0.1260	3.1851	0.2600
0.03558	0.04083	0.181477	7.850079	0.06640	0.1260	3.1735	0.2600
0.04258	0.04783	0.214728	9.433441	0.07960	0.1260	3.1658	0.2600
0.04958	0.05483	0.247978	11.016802	0.09280	0.1260	3.1604	0.2600
0.05658	0.06183	0.281229	12.600163	0.10604	0.1260	3.1575	0.2600
0.06358	0.06883	0.314479	14.183525	0.11925	0.1260	3.1544	0.2600
0.07058	0.07583	0.347730	15.766886	0.13250	0.1260	3.1529	0.2600
0.07758	0.08233	0.343622	17.350247	0.14567	0.1140	3.1500	0.2600
0.08408	0.08792	0.298794	18.820511	0.15794	0.0922	3.1485	0.2600
0.08917	0.09917		9.943509	0.00600		0.2264	0.2300
							0.0500

PLATE TEMPERATURES FOR ALL INCREMENTS, DEGREES R

INCREMENT NO. M	1	2	3	4	5	6	7	8	9	10
1	3927.2	3949.3	3963.3	3975.2	3986.4	3997.8	4007.8	4017.9	4028.1	4038.1
2	4347.9	4512.1	4568.1	4599.5	4621.6	4642.1	4654.6	4666.0	4679.9	4588.5
3	4347.9	4520.8	4582.2	4616.6	4640.5	4659.2	4674.7	4688.4	4706.9	4715.1
4	4341.9	4514.3	4575.7	4610.1	4634.0	4652.6	4668.2	4682.0	4700.6	4708.9
5	4330.9	4503.1	4564.5	4598.8	4622.7	4641.4	4657.0	4670.7	4689.3	4697.6
6	4321.9	4493.9	4555.3	4589.6	4613.5	4632.1	4647.7	4661.4	4680.1	4688.3
7	4317.3	4489.3	4550.6	4585.0	4608.9	4627.5	4643.1	4656.9	4675.5	4683.7
8	4321.8	4493.7	4555.1	4589.4	4613.3	4631.9	4647.5	4661.3	4679.9	4688.2
9	4344.3	4515.3	4576.1	4610.2	4633.8	4652.2	4667.7	4681.3	4699.7	4707.8
10	4354.8	4520.2	4578.0	4610.1	4632.3	4649.5	4664.0	4676.7	4692.6	4700.1
11	4048.3	4203.1	4256.3	4286.4	4307.7	4324.7	4342.8	4352.8	4363.4	4372.0
12	3295.5	3316.8	3330.5	3342.3	3353.5	3364.2	3375.0	3385.1	3395.1	3405.0
13	727.0	727.1	727.2	727.3	727.4	727.5	727.6	727.7	727.8	727.9
AV FUEL TEMP	4257.0	4424.2	4483.3	4516.4	4539.5	4557.8	4573.5	4586.4	4603.2	4611.4
AV GAS TEMP	3900.4	3909.6	3918.8	3928.0	3937.1	3946.2	3955.4	3964.5	3973.6	3982.7
DIFF IN TEMP	356.6	514.6	564.5	588.4	602.4	611.5	618.1	621.9	629.6	628.7

STAGE AVERAGE FUEL TEMP = 4515.3 DEG R
STAGE AVERAGE OUTLET GAS TEMP = 3991.8 DEG R
STAGE AVERAGE OUTLET DYNAMIC HEAD = 10.2299 PSI

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COMPUTED TEMPERATURES AND PRESSURES. STAGE NO. 17

	PLATE TEMPERATURES			GAS TEMPERATURES		
	ENTRANCE	CENTER	EXIT	ENTRANCE	CENTER	EXIT
CENTER PLUG	3927.	3986.	4038.	3903.	3952.	4002.
FUEL RINGS	4348	4622.	4688.	3995.	4041.	4087.
	4348.	4641.	4715.	3996.	4043.	4089.
	4342.	4634.	4709.	3986.	4032.	4078.
	4331.	4623.	4698.	3975.	4022.	4068.
	4322.	4614.	4688.	3968.	4015.	4061.
	4317.	4609.	4684.	3966.	4013.	4059.
	4322.	4613.	4688.	3978.	4025.	4071.
	4344.	4634.	4708.	4013.	4058.	4103.
	4355.	4632.	4700.	3988.	4024.	4063.
	4048.	4308.	4372.	3278.	3332.	3383.
RADTN SHIELDS	3295.	3353.	3405.			
CONTAINMNT SHELL	727.	727.	728.			

PASSAGE PRESSURE DROPS, PSF			MASS FLOW RATE			
FRICTION	MOMENTUM	TOTAL	LB/SEC-FT**2	PASSAGE WT FLOW, LB/SEC	EXIT MACH NO.	EXIT DYNAMIC HEAD, PSI
609.2	69.1	678.3	46.627	0.01809	0.1332	7.6092
495.3	86.1	581.4	54.386	0.04343	0.1574	10.5952
495.2	86.3	581.5	54.373	0.05597	0.1574	10.5947
494.8	86.6	581.4	54.452	0.06863	0.1574	10.5980
494.5	86.8	581.3	54.533	0.08132	0.1574	10.6024
494.4	86.9	581.3	54.588	0.09401	0.1574	10.6052
494.2	87.2	581.4	54.598	0.10663	0.1574	10.6050
494.4	87.2	581.6	54.504	0.11903	0.1573	10.5991
496.6	84.0	580.6	54.281	0.13109	0.1574	10.5948
528.1	70.3	598.4	52.807	0.12609	0.1523	9.9264
555.7	93.2	648.9	54.173	0.11231	0.1411	8.6877

STAGE END PRESSURE DROPS, PSF					TOTAL	REYNOLDS NUMBERS		
CONTRACTION		ENLARGEMENT			PRESSURE	ENTRANCE	CENTER	EXIT
FRICTION	MOMENTUM	FRICTION	MOMENTUM	TOTAL	DROP, PSF			
193.1	452.0	65.5	-470.0	240.7	918.9	14235.	14148.	14039.
269.0	629.6	91.2	-654.1	335.6	917.0	25197.	25036.	24837.
268.9	629.4	91.2	-654.1	335.5	917.0	25187.	25025.	24825.
269.0	629.6	91.2	-654.3	335.5	917.0	25265.	25108.	24907.
269.1	629.8	91.2	-654.6	335.6	917.0	25343.	25191.	24989.
269.2	630.0	91.3	-654.7	335.7	917.0	25396.	25248.	25045.
269.1	629.9	91.3	-654.7	335.6	917.0	25409.	25261.	25057.
269.0	629.6	91.2	-654.4	335.4	917.0	25319.	25165.	24962.
269.2	630.0	91.2	-654.1	336.2	916.8	25071.	24914.	24721.
253.1	592.4	85.4	-612.9	318.1	916.5	22161.	22055.	21905.
219.0	512.5	74.8	-536.6	269.7	918.5	20842.	20663.	20462.

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INPUT DATA, STAGE NO. 18
STAGE POWER= 334.2 BTU/SEC
NUMBER OF RINGS=10
NUMBER OF SHIELDS= 1
STAGE LENGTH= 0.1250 FT.
ENTRANCE PRESSURE= 94979.2 PSF
HEAT LOSS= 1.7184 BTU/SEC

PASSAGE RADII,FT INNER	OUTER	F AREA,SQIN	S AREA,SQIN	RNG PWR DIST	EFF	DIAM,IN	PWR DENSITY BTU/SEC SQIN	EMISSIVITY
0.01642	0.01983	0.055921	1.857057	0.00060		0.0818	0.1080	0.2300
0.02158	0.02683	0.114976	4.683357	0.04000		0.1260	2.8541	0.2600
0.02858	0.03383	0.148226	6.266718	0.05320		0.1260	2.8369	0.2600
0.03558	0.04083	0.181477	7.850079	0.06640		0.1260	2.8266	0.2600
0.04258	0.04783	0.214728	9.433441	0.07960		0.1260	2.8198	0.2600
0.04958	0.05483	0.247978	11.016802	0.09280		0.1260	2.8149	0.2600
0.05658	0.06183	0.281229	12.600163	0.10604		0.1260	2.8123	0.2600
0.06358	0.06883	0.314479	14.183525	0.11925		0.1260	2.8095	0.2600
0.07058	0.07583	0.347730	15.766886	0.13250		0.1260	2.8083	0.2600
0.07758	0.08233	0.343622	17.350247	0.14567		0.1140	2.8057	0.2600
0.08408	0.08792	0.298794	18.820511	0.15794		0.0922	2.8044	0.2600
0.08917	0.09917		9.943509	0.00600			0.2016	0.2300
								0.0500

PLATE TEMPERATURES FOR ALL INCREMENTS, DEGREES R

INCREMENT NO. N	1	2	3	4	5	6	7	8	9	10
1	4073.6	4043.1	4055.4	4066.0	4075.9	4085.9	4094.8	4103.7	4112.7	4121.6
2	4392.6	4535 2	4584.0	4611.5	4630.9	4648.9	4659.9	4670.0	4682.4	4690.0
3	4394.9	4545.1	4598.6	4628.6	4649.6	4666.0	4679.7	4691.9	4708.2	4715.5
4	4389.3	4539.1	4592.6	4622.6	4643.6	4660.0	4673.8	4686.0	4702.4	4709.8
5	4378.5	4528.2	4581.5	4611.5	4632.5	4648.9	4662.7	4674.9	4691.3	4698.7
6	4369.5	4519.1	4572.4	4602.4	4623.3	4639.7	4653.5	4665.7	4682.1	4689.5
7	4365.1	4514.6	4568.0	4598.0	4618.9	4635.3	4649.1	4661.3	4677.7	4685.1
8	4370.0	4519.4	4572.7	4602.7	4623.6	4640.0	4653.8	4666.0	4682.5	4689.9
9	4390.8	4539.3	4592.2	4621.9	4642.6	4658.8	4672.4	4684.3	4700.5	4707.8
10	4391.1	4534.6	4584.8	4612.7	4632.0	4647.1	4659.8	4670.9	4684.8	4691.5
11	4090.5	4225.4	4271.8	4298.0	4316.7	4331.5	4347.5	4356.2	4365.4	4373.0
12	3395.4	3413.7	3425.8	3436.4	3446.3	3456.0	3465.7	3474.8	3483.8	3492.8
13	728.0	728.1	728.2	728.3	728.4	728.5	728.6	728.7	728.8	728.9
AV FUEL TEMP	4303.4	4448.7	4500.1	4529.0	4549.3	4565.3	4579.2	4590.7	4605.4	4612.8
AV GAS TEMP	3991.8	3999.9	4008.0	4016.1	4024.1	4032.2	4040.2	4048.2	4056.2	4064.2
DIFF IN TEMP	311.5	448.8	492.1	513.0	525.2	533.2	539.0	542.4	549.2	548.6

STAGE AVERAGE FUEL TEMP = 4528.4 DEG R
STAGE AVERAGE OUTLET GAS TEMP = 4072.3 DEG R
STAGE AVERAGE OUTLET DYNAMIC HEAD = 10.5465 PSI

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MOORE BUSINESS FORMS INC FORM 3514
E40-

COMPUTED TEMPERATURES AND PRESSURES. STAGE NO. 18

	PLATE TEMPERATURES ENTRANCE	CENTER	EXIT	GAS TEMPERATURES ENTRANCE	CENTER	EXIT
CENTER PLUG	4024.	4076.	4122.	4002.	4045.	4090.
FUEL RINGS	4393.	4631.	4690.	4087.	4128.	4168.
	4395.	4650.	4716.	4089.	4129.	4170.
	4389.	4644.	4710.	4078.	4119.	4159.
	4378.	4632.	4699.	4068.	4109.	4149.
	4369.	4623.	4690.	4061.	4101.	4142.
	4365.	4619.	4685.	4059.	4100.	4141.
	4370.	4624.	4690.	4071.	4112.	4153.
	4391.	4643.	4708.	4103.	4142.	4180.
	4391.	4632.	4692.	4061.	4092.	4126.
	4091.	4317.	4373.	3383.	3432.	3477.
RADTN SHIELDS	3395.	3446.	3493.			
CONTAINMNT SHELL	728.	728.	729.			

PASSAGE PRESSURE DROPS,PSF FRICTION	MOMENTUM	TOTAL	MASS FLOW RATE LB/SEC-FT**2	PASSAGE WT FLOW,LB/SEC	EXIT MACH NO.	EXIT DYNAMIC HEAD,PSI
632.5	64.3	696.8	46.537	0.01806	0.1359	7.8253
516.0	79.6	595.7	54.408	0.04344	0.1608	10.9251
515.9	79.9	595.8	54.392	0.05599	0.1608	10.9239
515.5	80.2	595.8	54.468	0.06865	0.1608	10.9275
515.3	80.4	595.7	54.546	0.08134	0.1608	10.9317
515.1	80.6	595.6	54.600	0.09403	0.1608	10.9349
514.9	80.8	595.7	54.607	0.10665	0.1608	10.9342
515.2	80.7	595.9	54.515	0.11906	0.1608	10.9286
517.5	77.2	594.7	54.331	0.13121	0.1608	10.9275
548.8	64.9	613.7	52.944	0.12642	0.1555	10.2367
578.8	87.3	666.0	53.907	0.11176	0.1440	8.9353

STAGE END PRESSURE DROPS, PSF CONTRACTION FRICTION	MOMENTUM	ENLARGEMENT FRICTION	MOMENTUM	TOTAL	TOTAL PRESSURE DROP,PSF	REYNOLDS NUMBERS ENTRANCE	CENTER	EXIT
199.2	466.2	67.4	-483.3	249.4	946.2	13990.	13904.	13798.
278.1	650.8	94.0	-674.4	348.4	944.1	24808.	24673.	24512.
278.0	650.6	94.0	-674.4	348.3	944.1	24794.	24659.	24497.
278.1	650.8	94.0	-674.6	348.3	944.1	24874.	24736.	24572.
278.2	651.0	94.1	-674.8	348.4	944.1	24955.	24814.	24649.
278.2	651.1	94.1	-675.0	348.4	944.1	25010.	24868.	24702.
278.2	651.1	94.1	-675.0	348.4	944.1	25020.	24878.	24711.
278.1	650.8	94.0	-674.6	348.2	944.1	24927.	24785.	24621.
278.3	651.4	94.0	-674.6	349.2	943.9	24767.	24581.	24426.
261.6	612.3	88.1	-632.0	330.0	943.7	21941.	21847.	21723.
225.9	528.7	76.9	-551.8	279.7	945.8	20322.	20168.	19994.

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FORM 3811
MOORE BUSINESS FORMS INC

INPUT DATA, STAGE NO. 19
STAGE POWER= 297.7 BTU/SEC
NUMBER OF RINGS=10
NUMBER OF SHIELDS= 1
STAGE LENGTH= 0.1250 FT.
ENTRANCE PRESSURE= 94034.8 PSF
HEAT LOSS= 1.8054 BTU/SEC

PASSAGE RADII,FT	INNER	OUTER	F AREA,SQIN	S AREA,SQIN	RNG PWR DIST	EFF DIAM,IN	PWR DENSITY BTU/SECSQIN	EMISSIVITY
	0.01642	0.01983	0.055921	1.857057	0.00060	0.0818	0.0962	0.2300
	0.02158	0.02683	0.114976	4.683357	0.04000	0.1260	2.5428	0.7600
	0.02858	0.03383	0.148226	6.266718	0.05320	0.1260	2.5274	0.2600
	0.03558	0.04083	0.181477	7.850079	0.06640	0.1260	2.5183	0.2600
	0.04258	0.04783	0.214728	9.433441	0.07960	0.1260	2.5122	0.2600
	0.04958	0.05483	0.247978	11.016802	0.09280	0.1260	2.5078	0.2600
	0.05658	0.06183	0.281229	12.600163	0.10604	0.1260	2.5055	0.2600
	0.06358	0.06883	0.314479	14.183525	0.11925	0.1260	2.5031	0.2600
	0.07058	0.07583	0.347730	15.766886	0.13250	0.1260	2.5019	0.2600
	0.07758	0.08233	0.343622	17.350247	0.14567	0.1140	2.4996	0.2600
	0.08408	0.08792	0.298794	18.820511	0.15794	0.0922	2.4984	0.2600
	0.08917	0.09917		9.943509	0.00600		0.1796	0.2300
								0.0500

PLATE TEMPERATURES FOR ALL INCREMENTS, DEGREES R

INCREMENT NO. M	1	2	3	4	5	6	7	8	9	10
1	4108.9	4126.2	4137.1	4146.4	4155.2	4164.0	4171.9	4179.8	4187.7	4195.6
2	4433.5	4557.8	4600.4	4624.5	4641.5	4657.4	4667.1	4676.1	4687.1	4693.9
3	4437.3	4568.5	4615.2	4641.5	4659.9	4674.3	4686.4	4697.1	4711.4	4718.0
4	4432.2	4563.0	4609.7	4636.0	4654.4	4668.8	4681.0	4691.7	4706.1	4712.7
5	4421.6	4552.2	4598.9	4625.2	4643.6	4658.0	4670.1	4680.9	4695.3	4701.9
6	4412.6	4543.2	4589.8	4616.1	4634.5	4648.9	4661.1	4671.8	4686.3	4692.9
7	4408.4	4539.0	4585.6	4611.9	4630.3	4644.7	4656.9	4667.6	4682.1	4688.7
8	4413.5	4544.0	4590.5	4616.8	4635.2	4649.6	4661.8	4672.6	4687.0	4693.6
9	4432.4	4561.9	4608.1	4634.0	4652.2	4666.3	4678.3	4688.8	4703.0	4709.4
10	4422.9	4548.0	4591.7	4616.0	4632.9	4646.1	4657.2	4666.9	4679.1	4685.0
11	4128.3	4246.0	4286.5	4309.5	4325.8	4338.9	4353.0	4360.6	4368.6	4375.4
12	3486.1	3501.7	3512.4	3521.8	3530.8	3539.4	3548.2	3556.4	3564.6	3572.7
13	729.0	729.1	729.2	729.3	729.4	729.5	729.6	729.7	729.8	729.9
AV FUEL TEMP	4345.3	4472.1	4517.0	4542.3	4560.1	4574.2	4586.4	4596.5	4609.5	4616.1
AV GAS TEMP	4072.3	4079.4	4086.5	4093.6	4100.7	4107.7	4114.8	4121.9	4128.9	4135.9
DIFF IN TEMP	273.0	392.7	430.5	448.7	459.4	466.5	471.6	474.7	480.6	480.1

STAGE AVERAGE FUEL TEMP = 4541.9 DEG R
STAGE AVERAGE OUTLET GAS TEMP = 4143.0 DEG R
STAGE AVERAGE OUTLET DYNAMIC HEAD = 10.8471 PSI

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COMPUTED TEMPERATURES AND PRESSURES. STAGE NO. 19

	PLATE TEMPERATURES			GAS TEMPERATURES		
	ENTRANCE	CENTER	EXIT	ENTRANCE	CENTER	EXIT
CENTER PLUG	4109.	4155.	4196.	4090.	4128.	4167.
FUEL RINGS	4433.	4642.	4694.	4168.	4203.	4238.
	4437.	4660.	4718.	4170.	4205.	4241.
	4432.	4654.	4713.	4159.	4195.	4231.
	4427.	4644.	4702.	4149.	4185.	4220.
	4413.	4634.	4693.	4142.	4178.	4213.
	4408.	4630.	4689.	4141.	4177.	4212.
	4414.	4635.	4694.	4153.	4189.	4224.
	4432.	4652.	4709.	4180.	4214.	4247.
	4423.	4633.	4685.	4124.	4151.	4180.
	4128.	4326.	4375.	3477.	3522.	3564.
RADTN SHIELDS	3486.	3531.	3573.			
CONTAINMNT SHELL	729.	729.	730.			

PASSAGE PRESSURE DROPS,PSF			MASS FLOW RATE			
FRICTION	MOMENTUM	TOTAL	LB/SEC-FT**2	PASSAGE WT FLOW,LB/SEC	EXIT MACH NO.	EXIT DYNAMIC HEAD,PSI
654.4	60.1	714.4	46.460	0.01803	0.1386	8.0323
535.4	74.1	609.5	54.429	0.04346	0.1641	11.2385
535.3	74.3	609.6	54.410	0.05601	0.1641	11.2372
534.9	74.7	609.6	54.483	0.06866	0.1641	11.2406
534.6	74.9	609.5	54.559	0.08136	0.1641	11.2447
534.4	75.1	609.5	54.611	0.09405	0.1641	11.2474
534.3	75.3	609.6	54.616	0.10667	0.1641	11.2470
534.6	75.0	609.7	54.527	0.11908	0.1641	11.2419
536.9	71.5	608.4	54.381	0.13133	0.1642	11.2435
568.2	60.3	628.5	53.068	0.12671	0.1587	10.5309
600.4	82.2	682.6	53.655	0.11124	0.1468	9.1681

STAGE END PRESSURE DROPS, PSF					TOTAL	REYNOLDS NUMBERS		
CONTRACTION		ENLARGEMENT			PRESSURE	ENTRANCE	CENTER	EXIT
FRICTION	MOMENTUM	FRICTION	MOMENTUM	TOTAL	DROP,PSF			
204.9	479.6	69.2	-496.1	257.6	972.0	13753.	13682.	13596.
286.6	670.8	96.7	-693.7	360.4	969.8	24490.	24376.	24251.
286.5	670.6	96.7	-693.6	360.3	969.9	24473.	24360.	24235.
286.6	670.8	96.7	-693.8	360.3	969.9	24546.	24432.	24302.
286.7	671.0	96.8	-694.1	360.3	969.9	24622.	24508.	24372.
286.7	671.1	96.8	-694.3	360.4	969.9	24674.	24559.	24420.
286.7	671.0	96.8	-694.2	360.3	969.9	24682.	24566.	24426.
286.6	670.8	96.7	-693.9	360.2	969.9	24593.	24478.	24344.
287.0	671.6	96.7	-694.0	361.3	969.7	24418.	24315.	24197.
269.6	631.0	90.6	-650.1	341.1	969.6	21758.	21683.	21580.
232.4	543.9	78.9	-566.2	289.0	971.6	19866.	19730.	19573.

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INPUT DATA, STAGE NO. 20
STAGE POWER= 268.9 BTU/SEC
NUMBER OF RINGS=10
NUMBER OF SHIELDS= 1
STAGE LENGTH= 0.1250 FT.
ENTRANCE PRESSURE= 93064.6 PSF
HEAT LOSS= 1.8877 BTU/SEC

PASSAGE RADII, FT INNER	OUTER	F AREA, SQIN	S AREA, SQIN	RNG PWR DIST	EFF DIAM, IN	PWR DENSITY BTU/SEC SQIN	EMISSIVITY
0.01642	0.01983	0.055921	1.857057	0.00060	0.0818	0.0869	0.2300
0.02158	0.02683	0.114976	4.583357	0.04000	0.1260	2.2963	0.2600
0.02858	0.03383	0.148226	6.266718	0.05320	0.1260	2.2824	0.2600
0.03558	0.04083	0.181477	7.850079	0.06640	0.1260	2.2741	0.2600
0.04258	0.04783	0.214728	9.433441	0.07960	0.1260	2.2686	0.2600
0.04958	0.05483	0.247978	11.016802	0.09280	0.1260	2.2647	0.2600
0.05658	0.06183	0.281229	12.600163	0.10604	0.1260	2.2626	0.2600
0.06358	0.06883	0.314479	14.183525	0.11925	0.1260	2.2605	0.2600
0.07058	0.07583	0.347730	15.766886	0.13250	0.1260	2.2594	0.2600
0.07758	0.08233	0.343622	17.350247	0.14567	0.1140	2.2573	0.2600
0.08408	0.08792	0.298794	18.820511	0.15794	0.0922	2.2562	0.2600
0.08917	0.09917		9.943509	0.00600		0.1622	0.2300
							0.0500

PLATE TEMPERATURES FOR ALL INCREMENTS, DEGREES R

INCREMENT NO. M	1	2	3	4	5	6	7	8	9	10
1	4184.7	4200.2	4209.9	4218.3	4226.1	4234.0	4241.0	4248.1	4255.2	4262.2
2	4474.0	4584.4	4622.1	4643.6	4658.8	4672.9	4681.7	4689.8	4699.5	4705.7
3	4478.5	4595.0	4636.4	4659.8	4676.2	4689.1	4699.9	4709.4	4722.3	4728.2
4	4473.8	4590.0	4631.4	4654.8	4671.2	4684.0	4694.9	4704.5	4717.4	4723.3
5	4463.4	4579.5	4620.8	4644.2	4660.6	4673.5	4684.3	4693.9	4706.9	4712.8
6	4454.6	4570.6	4611.9	4635.3	4651.7	4664.5	4675.4	4685.0	4697.9	4703.9
7	4450.6	4566.6	4607.9	4631.3	4647.7	4660.5	4671.4	4681.1	4694.0	4699.9
8	4455.8	4571.7	4612.9	4636.3	4652.7	4665.5	4676.4	4686.0	4699.0	4704.9
9	4472.4	4587.4	4628.2	4651.3	4667.4	4680.0	4690.6	4700.0	4712.6	4718.4
10	4454.0	4564.9	4603.5	4625.1	4640.0	4651.7	4661.6	4670.2	4681.0	4686.2
11	4165.8	4270.3	4306.1	4326.6	4341.2	4352.8	4365.2	4371.9	4378.8	4384.7
12	3568.9	3582.3	3591.8	3600.3	3608.4	3616.3	3624.2	3631.7	3639.2	3646.7
13	730.0	730.1	730.2	730.3	730.4	730.5	730.6	730.7	730.8	730.9
AV FUEL TEMP	4386.1	4498.7	4538.4	4561.0	4576.8	4589.4	4600.3	4609.3	4620.8	4626.7
AV GAS TEMP	4143.0	4149.4	4155.7	4162.0	4168.4	4174.7	4181.0	4187.3	4193.5	4199.8
DIFF IN TEMP	243.0	349.3	382.7	398.9	408.5	414.7	419.3	422.0	427.3	426.9

STAGE AVERAGE FUEL TEMP = 4560.7 DEG R
STAGE AVERAGE OUTLET GAS TEMP = 4206.2 DEG R
STAGE AVERAGE OUTLET DYNAMIC HEAD = 11.1371 PSI

COMPUTED TEMPERATURES AND PRESSURES. STAGE NO. 20

	PLATE TEMPERATURES			GAS TEMPERATURES		
	ENTRANCE	CENTER	EXIT	ENTRANCE	CENTER	EXIT
CENTER PLUG	4185.	4276.	4262.	4167.	4202.	4237.
FUEL RINGS	4474.	4659.	4706.	4238.	4270.	4301.
	4479.	4676.	4728.	4241.	4272.	4304.
	4474.	4671.	4723.	4231.	4263.	4294.
	4463.	4661.	4713.	4220.	4252.	4284.
	4455.	4652.	4704.	4213.	4245.	4277.
	4451.	4648.	4700.	4212.	4245.	4276.
	4456.	4653.	4705.	4224.	4256.	4288.
	4472.	4667.	4718.	4247.	4277.	4307.
	4454.	4640.	4686.	4178.	4201.	4227.
	4166.	4341.	4385.	3564.	3605.	3643.
RADTN SHIELDS	3569.	3608.	3647.			
CONTAINMNT SHELL	730.	730.	731.			

PASSAGE PRESSURE DROPS,PSF			MASS FLOW RATE			
FRICTION	MOMENTUM	TOTAL	LB/SEC-FT**2	PASSAGE WT FLOW,LB/SEC	EXIT MACH NO.	EXIT DYNAMIC HEAD,PSI
675.1	57.0	732.1	46.396	0.01801	0.1412	8.2338
553.5	70.2	623.6	54.446	0.04347	0.1674	11.5401
553.4	70.3	623.7	54.426	0.05603	0.1673	11.5386
553.0	70.7	623.7	54.495	0.06868	0.1673	11.5423
552.8	70.9	623.6	54.570	0.08138	0.1674	11.5465
552.6	71.1	623.6	54.620	0.09406	0.1674	11.5491
552.4	71.3	623.7	54.624	0.10668	0.1673	11.5486
552.8	70.9	623.7	54.539	0.11911	0.1673	11.5440
555.1	67.2	622.3	54.430	0.13145	0.1674	11.5475
586.3	57.2	643.5	53.181	0.12698	0.1618	10.8147
620.9	78.3	699.2	53.422	0.11075	0.1495	9.3946

STAGE END PRESSURE DROPS, PSF					TOTAL	REYNOLDS NUMBERS		
CONTRACTION		ENLARGEMENT			PRESSURE	ENTRANCE	CENTER	EXIT
FRICTION	MOMENTUM	FRICTION	MOMENTUM	TOTAL	DROP,PSF			
210.4	492.4	70.9	-508.5	265.2	997.3	13560.	13499.	13430.
294.7	689.7	99.3	-712.3	371.4	995.0	24235.	24146.	24038.
294.6	689.6	99.3	-712.2	371.3	995.0	24217.	24129.	24020.
294.7	689.7	99.3	-712.4	371.3	995.0	24283.	24194.	24084.
294.8	689.9	99.3	-712.6	371.4	995.0	24352.	24263.	24152.
294.8	690.1	99.4	-712.8	371.4	995.0	24399.	24309.	24198.
294.8	690.0	99.4	-712.8	371.4	995.1	24404.	24314.	24202.
294.7	689.8	99.3	-712.5	371.3	995.0	24324.	24235.	24124.
295.2	690.8	99.4	-712.7	372.6	994.9	24195.	24113.	24011.
277.2	648.7	93.1	-667.6	351.3	994.9	21612.	21548.	21467.
238.6	558.3	80.9	-580.1	297.7	996.8	19458.	19334.	19209.

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INPUT DATA. STAGE NO. 21
STAGE POWER= 240.0 BTU/SEC
NUMBER OF RINGS=10
NUMBER OF SHIELDS= 1
STAGE LENGTH= 0.1250 FT.
ENTRANCE PRESSURE= 92069.3 PSF
HEAT LOSS= 1.9650 BTU/SEC

PASSAGE RADII,FT INNER	OUTER	F AREA,SQIN	S AREA,SQIN	RNG PWR DIST	EFF DIAM,IN	PWR DENSITY BTU/SEC SQIN	EMISSIVITY
0.01642	0.01983	0.055921	1.857057	0.00060	0.0818	0.0775	0.2300
0.02158	0.02683	0.114976	4.683357	0.04000	0.1260	2.0498	0.2600
0.02858	0.03383	0.148226	6.266718	0.05320	0.1260	2.0374	0.2600
0.03558	0.04083	0.181477	7.850079	0.06640	0.1260	2.0300	0.2600
0.04258	0.04783	0.214728	9.433441	0.07960	0.1260	2.0251	0.2600
0.04958	0.05483	0.247978	11.016802	0.09280	0.1260	2.0216	0.2600
0.05658	0.06183	0.281229	12.600163	0.10604	0.1260	2.0198	0.2600
0.06358	0.06883	0.314479	14.183525	0.11925	0.1260	2.0178	0.2600
0.07058	0.07583	0.347730	15.766886	0.13250	0.1260	2.0169	0.2600
0.07758	0.08233	0.343622	17.350247	0.14567	0.1140	2.0150	0.2600
0.08408	0.08792	0.298794	18.820511	0.15794	0.0922	2.0140	0.2600
0.08917	0.09917		9.943509	0.07600		0.1448	0.2300
							0.0500

PLATE TEMPERATURES FOR ALL INCREMENTS. DEGREES R

INCREMENT NO. M	1	2	3	4	5	6	7	8	9	10
1	4252.3	4266.0	4274.6	4282.0	4288.9	4295.9	4302.1	4308.4	4314.7	4320.9
2	4508.0	4604.9	4637.9	4656.8	4670.1	4682.5	4690.2	4697.3	4705.9	4711.3
3	4513.2	4615.4	4651.5	4672.1	4686.4	4697.6	4707.0	4715.3	4726.4	4731.5
4	4508.9	4610.9	4647.0	4667.6	4681.9	4693.1	4702.5	4710.8	4722.1	4727.2
5	4498.7	4600.7	4636.9	4657.5	4671.8	4683.0	4692.5	4700.8	4712.1	4717.2
6	4490.0	4592.0	4628.2	4648.9	4663.3	4674.5	4683.9	4692.3	4703.5	4708.7
7	4486.2	4588.1	4624.4	4645.1	4659.5	4670.8	4680.3	4688.6	4699.9	4705.0
8	4491.4	4593.2	4629.4	4650.0	4664.4	4675.6	4685.1	4693.4	4704.7	4709.8
9	4505.6	4606.4	4642.1	4662.3	4676.3	4687.3	4696.5	4704.6	4715.6	4720.5
10	4478.8	4575.9	4609.6	4628.5	4641.6	4651.7	4660.3	4667.8	4677.2	4681.7
11	4196.3	4287.7	4318.9	4336.8	4349.6	4359.8	4370.9	4376.7	4382.8	4388.1
12	3644.7	3655.9	3664.2	3671.8	3679.1	3686.2	3693.3	3700.1	3707.0	3713.8
13	731.0	731.1	731.2	731.3	731.4	731.5	731.6	731.7	731.8	731.9
AV FUEL TEMP	4420.2	4519.0	4553.8	4573.6	4587.5	4598.5	4608.0	4615.9	4625.9	4631.1
AV GAS TEMP	4206.2	4211.8	4217.4	4222.9	4228.5	4234.1	4239.7	4245.2	4250.8	4256.3
DIFF IN TEMP	214.0	307.3	336.4	350.7	359.0	364.4	368.4	370.6	375.2	374.8

STAGE AVERAGE FUEL TEMP = 4573.4 DEG R
STAGE AVERAGE OUTLET GAS TEMP = 4261.9 DEG R
STAGE AVERAGE OUTLET DYNAMIC HEAD = 11.4156 PSI

COMPUTED TEMPERATURES AND PRESSURES. STAGE NO. 21

	PLATE TEMPERATURES			GAS TEMPERATURES		
	ENTRANCE	CENTER	EXIT	ENTRANCE	CENTER	EXIT
CENTER PLUG	4252.	4289.	4321.	4237.	4267.	4298.
FUEL RINGS	4508.	4670.	4711.	4301.	4329.	4357.
	4513.	4686.	4732.	4304.	4332.	4360.
	4509.	4682.	4727.	4294.	4322.	4350.
	4499.	4672.	4717.	4284.	4312.	4340.
	4490.	4663.	4709.	4277.	4305.	4333.
	4486.	4660.	4705.	4276.	4305.	4333.
	4491.	4664.	4710.	4288.	4316.	4344.
	4506.	4676.	4720.	4307.	4332.	4358.
	4479.	4642.	4682.	4226.	4246.	4268.
	4196.	4350.	4388.	3643.	3681.	3716.
RADTN SHIELDS	3645.	3679.	3714.			
CONTAINMNT SHELL	731.	731.	732.			

PASSAGE PRESSURE DROPS,PSF			MASS FLOW RATE			
FRICTION	MOMENTUM	TOTAL	LB/SEC-FT**2	PASSAGE WT FLOW,LB/SEC	EXIT MACH NO.	EXIT DYNAMIC HEAD,PSI
695.1	53.9	749.0	46.338	0.01798	0.1438	8.4278
570.9	66.3	637.2	54.462	0.04349	0.1706	11.8294
570.8	66.4	637.3	54.441	0.05604	0.1706	11.8281
570.5	66.8	637.3	54.507	0.06869	0.1706	11.8315
570.2	67.0	637.2	54.580	0.08139	0.1706	11.8358
570.0	67.2	637.2	54.629	0.09408	0.1706	11.8389
569.9	67.3	637.2	54.631	0.10669	0.1705	11.8379
570.3	66.9	637.2	54.551	0.11914	0.1706	11.8338
572.6	63.2	635.8	54.478	0.13157	0.1706	11.8401
603.9	54.0	657.9	53.287	0.12723	0.1649	11.0888
640.6	74.5	715.2	53.201	0.11029	0.1522	9.6103

STAGE END PRESSURE DROPS, PSF					TOTAL	REYNOLDS NUMBERS		
CONTRACTION		ENLARGEMENT			PRESSURE	ENTRANCE	CENTER	EXIT
FRICTION	MOMENTUM	FRICTION	MOMENTUM	TOTAL	DROP,PSF			
215.7	504.8	72.5	-520.4	272.6	1021.6	13399.	13352.	13293.
302.5	707.9	101.8	-730.1	382.0	1019.2	24023.	23935.	23827.
302.4	707.8	101.8	-730.0	382.0	1019.2	24003.	23915.	23807.
302.5	707.9	101.8	-730.3	382.0	1019.2	24067.	23982.	23872.
302.6	708.2	101.8	-730.5	382.0	1019.2	24135.	24054.	23944.
302.6	708.3	101.9	-730.7	382.1	1019.3	24180.	24102.	23992.
302.6	708.2	101.9	-730.7	382.0	1019.3	24183.	24105.	23994.
302.5	708.1	101.8	-730.4	382.0	1019.2	24108.	24025.	23915.
303.0	709.2	101.9	-730.8	383.3	1019.1	24209.	23928.	23828.
284.5	665.8	95.4	-684.4	361.2	1019.1	21499.	21450.	21382.
244.5	572.2	82.7	-593.4	306.0	1021.1	19105.	19007.	18896.

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INPUT DATA. STAGE NO. 72
STAGE POWER= 212.7 BTU/SEC
NUMBER OF RINGS=10
NUMBER OF SHIELDS= 1
STAGE LENGTH= 0.1250 FT.
ENTRANCE PRESSURE= 91049.6 PSF
HEAT LOSS= 2.0379 BTU/SEC

PASSAGE RADII,FT INNER	OUTER	F AREA,SQIN	S AREA,SQIN	RNG PWR DIST	EFF	DIAM,IN	PWR DENSITY BTU/SEC SQIN	EMISSIVITY
0.01642	0.01983	0.055921	1.857057	0.00060	0.0818		0.0687	0.2300
0.02158	0.02683	0.114976	4.583357	0.04000	0.1260		1.8163	0.2600
0.02858	0.03383	0.148226	6.266718	0.05320	0.1260		1.8053	0.2600
0.03558	0.04083	0.181477	7.850079	0.06640	0.1260		1.7988	0.2600
0.04258	0.04783	0.214728	9.433441	0.07960	0.1260		1.7944	0.2600
0.04958	0.05483	0.247978	11.016802	0.09280	0.1260		1.7913	0.2600
0.05658	0.06183	0.281229	12.600163	0.10604	0.1260		1.7897	0.2600
0.06358	0.06883	0.314479	14.183525	0.11925	0.1260		1.7879	0.2600
0.07058	0.07583	0.347730	15.766886	0.13250	0.1260		1.7871	0.2600
0.07758	0.08233	0.343622	17.350247	0.14567	0.1140		1.7854	0.2600
0.08408	0.08792	0.298794	18.820511	0.15794	0.0922		1.7846	0.2600
0.08917	0.09917		9.943509	0.00600			0.1283	0.2300
								0.0500

PLATE TEMPERATURES FOR ALL INCREMENTS, DEGREES R

INCREMENT NO. M	1	2	3	4	5	6	7	8	9	10
1	4312.0	4324.1	4331.6	4338.1	4344.2	4350.3	4355.8	4361.2	4366.8	4372.2
2	4536.6	4620.9	4649.7	4666.2	4677.8	4688.6	4695.3	4701.5	4709.0	4713.8
3	4542.0	4631.0	4662.5	4680.4	4692.9	4702.7	4711.0	4718.3	4728.1	4732.7
4	4538.0	4626.8	4658.3	4676.3	4688.8	4698.6	4706.9	4714.2	4724.1	4728.7
5	4528.2	4617.0	4648.5	4666.5	4679.0	4688.8	4697.1	4704.5	4714.4	4718.9
6	4519.8	4608.6	4640.1	4658.0	4670.6	4680.4	4688.7	4696.1	4706.0	4710.5
7	4516.2	4605.0	4636.5	4654.5	4667.0	4676.9	4685.2	4692.6	4702.5	4707.1
8	4521.3	4609.9	4641.4	4659.3	4671.8	4681.6	4689.9	4697.3	4707.1	4711.7
9	4532.8	4620.5	4651.5	4669.1	4681.3	4690.9	4698.9	4706.0	4715.6	4719.9
10	4498.5	4583.0	4612.3	4628.7	4640.1	4648.9	4656.4	4662.9	4671.1	4675.0
11	4221.9	4301.4	4328.6	4344.3	4355.4	4364.4	4374.2	4379.3	4384.6	4389.4
12	3713.8	3722.8	3730.0	3736.8	3743.3	3749.7	3756.0	3762.2	3768.4	3774.5
13	732.0	732.1	732.2	732.3	732.4	732.5	732.6	732.7	732.8	732.9
AV FUEL TEMP	4448.8	4534.8	4565.1	4582.4	4594.5	4604.1	4612.5	4619.4	4628.2	4632.8
AV GAS TEMP	4261.9	4266.8	4271.7	4276.6	4281.5	4286.4	4291.3	4296.1	4301.0	4305.9
DIFF IN TEMP	186.9	268.0	293.4	305.7	313.0	317.7	321.2	323.2	327.2	326.9

STAGE AVERAGE FUEL TEMP = 4582.2 DEG R
STAGE AVERAGE OUTLET GAS TEMP = 4310.8 DEG R
STAGE AVERAGE OUTLET DYNAMIC HEAD = 11.6858 PSI

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COMPUTED TEMPERATURES AND PRESSURES. STAGE NO. 27

	PLATE TEMPERATURES ENTRANCE	CENTER	EXIT	GAS TEMPERATURES ENTRANCE	CENTER	EXIT
CENTER PLUG	4312.	4344.	4372.	4298.	4325.	4352.
FUEL RINGS	4537.	4678.	4714.	4357.	4381.	4405.
	4542.	4693.	4733.	4360.	4384.	4408.
	4538.	4689.	4729.	4350.	4375.	4399.
	4528.	4679.	4719.	4340.	4365.	4390.
	4520.	4671.	4711.	4333.	4358.	4383.
	4516.	4667.	4707.	4333.	4358.	4383.
	4521.	4672.	4712.	4344.	4369.	4393.
	4533.	4681.	4720.	4358.	4380.	4402.
	4499.	4640.	4675.	4267.	4284.	4303.
	4222.	4355.	4389.	3716.	3750.	3781.
RADTN SHIELDS	3714.	3743.	3774.			
CONTAINMNT SHELL	732.	732.	733.			

PASSAGE PRESSURE DROPS,PSF FRICTION	MOMENTUM	TOTAL	MASS FLOW RATE LB/SEC-FT**2	PASSAGE WT FLOW,LB/SEC	EXIT MACH NO.	EXIT DYNAMIC HEAD,PSI
714.3	51.2	765.5	46.286	0.01796	0.1464	8.6147
587.6	62.8	650.4	54.476	0.04350	0.1737	12.1101
587.6	62.9	650.5	54.454	0.05605	0.1737	12.1085
587.3	63.2	650.5	54.517	0.06871	0.1737	12.1126
587.0	63.4	650.4	54.589	0.08140	0.1737	12.1168
586.8	63.6	650.4	54.636	0.09409	0.1737	12.1195
586.7	63.8	650.4	54.637	0.10671	0.1737	12.1189
587.2	63.2	650.4	54.562	0.11916	0.1737	12.1154
589.3	59.5	648.8	54.525	0.13169	0.1738	12.1240
620.7	51.2	671.9	53.386	0.12747	0.1679	11.3539
659.6	71.0	730.7	52.994	0.10987	0.1549	9.8197

STAGE END PRESSURE DROPS, PSF CONTRACTION FRICTION	MOMENTUM	ENLARGEMENT FRICTION	MOMENTUM	TOTAL	TOTAL PRESSURE DROP,PSF	REYNOLDS NUMBERS ENTRANCE	CENTER	EXIT
220.8	516.7	74.2	-532.0	279.6	1045.1	13267.	13220.	13162.
310.0	725.5	104.2	-747.4	392.2	1042.6	23812.	23737.	23644.
309.9	725.4	104.2	-747.3	392.1	1042.6	23791.	23716.	23624.
310.0	725.5	104.2	-747.5	392.2	1042.6	23855.	23779.	23685.
310.1	725.7	104.2	-747.8	392.2	1042.6	23926.	23849.	23754.
310.1	725.8	104.3	-748.0	392.3	1042.6	23973.	23895.	23800.
310.1	725.8	104.3	-747.9	392.2	1042.6	23975.	23897.	23801.
310.1	725.7	104.2	-747.7	392.3	1042.6	23899.	23822.	23728.
310.6	727.0	104.3	-748.3	393.7	1042.5	23829.	23761.	23676.
291.5	682.3	97.7	-700.8	370.8	1042.6	21412.	21371.	21313.
250.2	585.5	84.5	-606.3	313.9	1044.6	18801.	18711.	18611.

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INPUT DATA, STAGE NO. 23
STAGE POWER= 186.8 BTU/SEC
NUMBER OF RINGS=10
NUMBER OF SHIELDS= 1
STAGE LENGTH= 0.1250 FT.
ENTRANCE PRESSURE= 90006.6 PSF
HEAT LOSS= 2.1054 BTU/SEC

PASSAGE RADII,FT INNER	OUTER	F AREA,SQIN	S AREA,SQIN	RNG PWR DIST	EFF	DIAM,IN	PWR DENSITY BTU/SEC SQIN	EMISSIVITY
0.01642	0.01983	0.055921	1.857057	0.00060		0.0818	0.0604	0.2300
0.02158	0.02683	0.114976	4.683357	0.04000		0.1260	1.5957	0.2600
0.02858	0.03383	0.148226	6.266718	0.05320		0.1260	1.5861	0.2600
0.03558	0.04083	0.181477	7.850079	0.06640		0.1260	1.5803	0.2600
0.04258	0.04783	0.214728	9.433441	0.07960		0.1260	1.5765	0.2600
0.04958	0.05483	0.247978	11.016802	0.09280		0.1260	1.5738	0.2600
0.05658	0.06183	0.281229	12.600163	0.10604		0.1260	1.5723	0.2600
0.06358	0.06883	0.314479	14.183525	0.11925		0.1260	1.5708	0.2600
0.07058	0.07583	0.347730	15.766886	0.13250		0.1260	1.5701	0.2600
0.07758	0.08233	0.343622	17.350247	0.14567		0.1140	1.5686	0.2600
0.08408	0.08792	0.298794	18.820511	0.15794		0.0922	1.5679	0.2600
0.08917	0.09917		9.943909	0.09600			0.1127	0.2300
								0.0500

PLATE TEMPERATURES FOR ALL INCREMENTS, DEGREES R

INCREMENT NO. M	1	2	3	4	5	6	7	8	9	10
1	4364.4	4375.0	4381.5	4387.2	4392.5	4397.8	4402.6	4407.4	4412.2	4417.0
2	4560.2	4633.2	4658.2	4572.5	4682.6	4692.1	4698.0	4703.5	4710.0	4714.2
3	4566.3	4643.4	4670.7	4686.3	4697.2	4705.9	4713.1	4719.6	4728.2	4732.2
4	4562.6	4639.5	4666.9	4682.5	4693.4	4702.0	4709.3	4715.8	4724.5	4728.5
5	4553.0	4629.9	4657.2	4672.8	4683.8	4692.4	4699.7	4706.2	4714.9	4718.9
6	4544.7	4621.6	4648.9	4564.5	4675.4	4684.0	4691.4	4697.9	4706.5	4710.6
7	4541.3	4618.1	4645.5	4661.1	4672.0	4680.6	4688.0	4694.5	4703.2	4707.3
8	4546.3	4622.9	4650.2	4665.7	4676.6	4685.2	4692.5	4699.0	4707.7	4711.7
9	4555.2	4631.0	4657.8	4573.1	4683.7	4692.0	4699.1	4705.3	4713.7	4717.5
10	4513.9	4586.9	4612.2	4626.3	4636.1	4643.7	4650.1	4655.7	4662.7	4666.1
11	4243.6	4312.1	4335.7	4349.3	4359.0	4366.8	4375.4	4379.8	4384.4	4388.6
12	3776.4	3783.4	3789.6	3795.5	3801.2	3806.9	3812.6	3818.1	3823.7	3829.2
13	733.0	733.0	733.0	733.0	733.0	733.0	733.0	733.0	733.0	733.0
AV FUEL TEMP	4472.8	4547.1	4573.4	4588.4	4598.9	4607.3	4614.7	4620.7	4628.4	4632.5
AV GAS TEMP	4310.8	4315.1	4319.3	4323.6	4327.8	4332.1	4336.3	4340.6	4344.8	4349.0
DIFF IN TEMP	162.0	232.1	254.0	264.8	271.1	275.2	278.4	280.2	283.6	283.4

STAGE AVERAGE FUEL TEMP = 4588.4 DEG R
STAGE AVERAGE OUTLET GAS TEMP = 4333.3 DEG R
STAGE AVERAGE OUTLET DYNAMIC HEAD = 11.9466 PSI

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COMPUTED TEMPERATURES AND PRESSURES. STAGE NO. 23

	PLATE TEMPERATURES ENTRANCE	CENTER	EXIT	GAS TEMPERATURES ENTRANCE	CENTER	EXIT
CENTER PLUG	4364.	4392.	4417.	4352.	4376.	4400.
FUEL RINGS	4560.	4683.	4714.	4405.	4427.	4448.
	4566.	4697.	4732.	4408.	4430.	4451.
	4563.	4693.	4729.	4399.	4421.	4442.
	4553.	4684.	4719.	4390.	4411.	4432.
	4545	4675.	4711.	4383.	4404.	4426.
	4541.	4672.	4707.	4383.	4404.	4426.
	4546.	4677.	4712.	4393.	4415.	4436.
	4555.	4684	4717.	4402.	4421.	4440.
	4514.	4636.	4666.	4302.	4316.	4332.
	4244.	4359.	4389.	3781.	3813.	3841.
RADTN SHIELDS	3776.	3801.	3829.			
CONTAINMNT SHELL	733.	733.	733.			

PASSAGE PRESSURE DROPS, PSF FRICTION	MOMENTUM	TOTAL	MASS FLOW RATE LB/SEC-FT**2	PASSAGE WT FLOW, LB/SEC	EXIT MACH NO.	EXIT DYNAMIC HEAD, PSI
732.7	48.8	781.5	46.240	0.01795	0.1490	8.7974
603.7	59.6	663.3	54.489	0.04351	0.1769	12.3816
603.7	59.6	663.3	54.466	0.05607	0.1769	12.3803
603.4	60.0	663.3	54.527	0.06872	0.1769	12.3834
603.1	60.2	663.3	54.596	0.08141	0.1769	12.3876
602.9	60.4	663.2	54.642	0.09410	0.1769	12.3902
602.8	60.5	663.3	54.641	0.10671	0.1769	12.3896
603.3	59.8	663.2	54.574	0.11919	0.1769	12.3869
605.4	56.1	661.5	54.572	0.13180	0.1770	12.3983
636.8	48.6	685.5	53.475	0.12768	0.1709	11.6095
678.0	67.7	745.7	52.803	0.10947	0.1576	10.0223

STAGE END PRESSURE DROPS, PSF CONTRACTION FRICTION	CONTRACTION MOMENTUM	ENLARGEMENT FRICTION	ENLARGEMENT MOMENTUM	TOTAL	TOTAL PRESSURE DROP, PSF	REYNOLDS NUMBERS ENTRANCE	CENTER	EXIT
225.7	528.2	75.7	-543.2	286.4	1067.9	13137.	13097.	13047.
317.2	742.4	106.5	-764.2	402.0	1065.3	23633.	23575.	23504.
317.2	742.3	106.5	-764.1	401.9	1065.3	23613.	23555.	23483.
317.2	742.5	106.5	-764.3	401.9	1065.3	23670.	23611.	23539.
317.3	742.7	106.6	-764.6	402.0	1065.3	23738.	23675.	23602.
317.4	742.8	106.6	-764.7	402.0	1065.3	23784.	23717.	23644.
317.3	742.7	106.6	-764.7	402.0	1065.3	23784.	23718.	23644.
317.3	742.7	106.6	-764.5	402.1	1065.3	23714.	23653.	23581.
318.0	744.2	106.7	-765.2	403.6	1065.1	23680.	23629.	23564.
298.3	698.2	99.9	-716.6	379.8	1065.3	21340.	21300.	21244.
255.7	598.5	86.3	-618.9	321.6	1067.3	18525.	18445.	18358.

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INPUT DATA, STAGE NO. 24
STAGE POWER= 165.6 BTU/SEC
NUMBER OF RINGS=10
NUMBER OF SHIELDS= 1
STAGE LENGTH= 0.1250 FT.
ENTRANCE PRESSURE= 88940.9 PSF
HEAT LOSS= 2.1681 BTU/SEC

PASSAGE RADII,FT INNER	OUTER	F AREA,SQIN	S AREA,SQIN	RNG PWR DIST	EFF	DIAM,IN	PWR DENSITY BTU/SEC SQIN	EMISSIVITY
0.01642	0.01983	0.055921	1.857057	0.00060	0.0818		0.0535	0.2300
0.02158	0.02683	0.114976	4.683357	0.04000	0.1260		1.4141	0.2600
0.02858	0.03383	0.148226	6.266718	0.05320	0.1260		1.4056	0.2600
0.03558	0.04083	0.181477	7.850079	0.06640	0.1260		1.4005	0.2600
0.04258	0.04783	0.214728	9.433441	0.07960	0.1260		1.3971	0.2600
0.04958	0.05483	0.247978	11.016802	0.09280	0.1260		1.3947	0.2600
0.05658	0.06183	0.281229	12.600163	0.10604	0.1260		1.3934	0.2600
0.06358	0.06883	0.314479	14.183525	0.11925	0.1260		1.3920	0.2600
0.07058	0.07583	0.347730	15.766886	0.13250	0.1260		1.3914	0.2600
0.07758	0.08233	0.343622	17.350247	0.14567	0.1140		1.3901	0.2600
0.08408	0.08792	0.298794	18.820511	0.15794	0.0922		1.3894	0.2600
0.08917	0.09917		9.943509	0.00600			0.0999	0.2300
								0.0500

PLATE TEMPERATURES FOR ALL INCREMENTS, DEGREES R

INCREMENT NO. M	1	2	3	4	5	6	7	8	9	10
1	4410.4	4419.7	4429.8	4430.8	4435.1	4439.9	4444.1	4448.3	4452.5	4456.7
2	4582.8	4646.6	4668.5	4681.1	4690.0	4698.4	4703.6	4708.5	4714.3	4718.0
3	4589.1	4656.7	4680.7	4694.3	4703.9	4711.5	4717.9	4723.5	4731.1	4734.7
4	4585.8	4653.2	4677.1	4690.8	4700.4	4708.0	4714.4	4720.1	4727.7	4731.3
5	4578.4	4643.8	4667.7	4681.5	4691.1	4698.6	4705.1	4710.8	4718.4	4722.0
6	4568.2	4635.6	4659.5	4673.3	4682.9	4690.5	4696.9	4702.7	4710.3	4713.9
7	4564.9	4632.3	4656.3	4670.0	4679.6	4687.2	4693.7	4699.4	4707.1	4710.7
8	4569.7	4636.8	4660.7	4674.4	4684.0	4691.5	4697.9	4703.6	4711.2	4714.8
9	4575.9	4642.2	4665.7	4679.0	4688.3	4695.6	4701.7	4707.2	4714.5	4717.8
10	4527.9	4591.6	4613.6	4625.9	4634.4	4641.1	4646.6	4651.5	4657.6	4660.5
11	4264.5	4324.2	4344.8	4356.7	4365.2	4372.1	4379.8	4383.7	4387.7	4391.4
12	3833.1	3838.4	3843.7	3848.9	3854.0	3859.1	3864.1	3869.1	3874.1	3879.1
13	733.0	733.1	733.2	733.3	733.4	733.5	733.6	733.7	733.8	733.9
AV FUEL TEMP	4495.3	4560.4	4583.3	4596.5	4605.8	4613.1	4619.6	4624.9	4631.7	4635.3
AV GAS TEMP	4353.3	4357.1	4360.8	4364.5	4368.3	4372.0	4375.7	4379.4	4383.1	4386.9
DIFF IN TEMP	142.0	203.3	222.5	232.0	237.5	241.2	243.9	245.5	248.5	248.4

STAGE AVERAGE FUEL TEMP = 4596.6 DEG R
STAGE AVERAGE OUTLET GAS TEMP = 4390.6 DEG R
STAGE AVERAGE OUTLET DYNAMIC HEAD = 12.2038 PSI

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COMPUTED TEMPERATURES AND PRESSURES. STAGE NO. 24

	PLATE TEMPERATURES			GAS TEMPERATURES		
	ENTRANCE	CENTER	EXIT	ENTRANCE	CENTER	EXIT
CENTER PLUG	4410.	4435.	4457.	4400.	4421.	4442.
FUEL RINGS	4583.	4690.	4718.	4448.	4466.	4485.
	4589.	4704.	4735.	4451.	4469.	4488.
	4586.	4700.	4731.	4442.	4461.	4480.
	4576.	4691.	4722.	4432.	4451.	4470.
	4568.	4683.	4714.	4426.	4445.	4464.
	4565.	4680.	4711.	4426.	4445.	4464.
	4570.	4684.	4715.	4436.	4454.	4473.
	4576.	4688.	4718.	4440.	4456.	4472.
	4528.	4634.	4661.	4331.	4343.	4357.
	4265.	4365.	4391.	3841.	3869.	3895.
RADTN SHIELDS	3833.	3854.	3879.			
CONTAINMNT SHELL	733.	733.	734.			

PASSAGE PRESSURE DROPS, PSF			MASS FLOW RATE			
FRICTION	MOMENTUM	TOTAL	LB/SEC-FT**2	PASSAGE WT FLOW, LB/SEC	EXIT MACH NO.	EXIT DYNAMIC HEAD, PSI
750.4	47.1	797.5	46.201	0.01793	0.1515	8.9768
619.1	57.3	676.3	54.500	0.04352	0.1801	12.6490
619.1	57.3	676.4	54.477	0.05608	0.1801	12.6477
618.7	57.6	676.4	54.535	0.06873	0.1801	12.6508
618.5	57.9	676.3	54.602	0.08142	0.1800	12.6548
618.3	58.0	676.3	54.646	0.09411	0.1800	12.6573
618.2	58.1	676.3	54.645	0.10672	0.1800	12.6568
618.8	57.4	676.1	54.585	0.11921	0.1801	12.6549
620.8	53.6	674.4	54.618	0.13191	0.1802	12.6688
652.2	47.1	699.3	53.555	0.12787	0.1739	11.8611
695.6	65.1	760.8	52.627	0.10910	0.1603	10.2229

STAGE END PRESSURE DROPS, PSF					TOTAL	REYNOLDS NUMBERS		
CONTRACTION		ENLARGEMENT			PRESSURE	ENTRANCE	CENTER	EXIT
FRICTION	MOMENTUM	FRICTION	MOMENTUM	TOTAL	DROP, PSF			
230.5	539.5	77.3	-554.3	292.9	1090.3	13026.	12995.	12955.
324.2	758.8	108.8	-780.6	411.3	1087.6	23494.	23444.	23382.
324.2	758.8	108.8	-780.5	411.2	1087.6	23474.	23424.	23361.
324.2	758.9	108.8	-780.7	411.2	1087.6	23528.	23477.	23414.
324.3	759.1	108.9	-781.0	411.3	1087.6	23590.	23539.	23475.
324.4	759.2	108.9	-781.1	411.3	1087.6	23631.	23580.	23516.
324.4	759.1	108.9	-781.1	411.3	1087.6	23631.	23579.	23515.
324.4	759.2	108.9	-781.0	411.4	1087.6	23572.	23521.	23459.
325.1	760.8	109.0	-781.8	413.0	1087.4	23572.	23520.	23473.
304.9	713.6	102.0	-732.0	388.5	1087.8	21268.	21235.	21187.
261.1	611.0	88.0	-631.2	328.9	1089.7	18279.	18209.	18131.

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INPUT DATA, STAGE NO. 25
STAGE POWER= 147.3 BTU/SEC
NUMBER OF RINGS=10
NUMBER OF SHIELDS= 1
STAGE LENGTH= 0.1250 FT.
ENTRANCE PRESSURE= 87852.9 PSF
HEAT LOSS= 2.2250 BTU/SEC

PASSAGE RADII,FT INNER	OUTER	F AREA,SQIN	S AREA,SQIN	RNG PWR DIST	EFF DIAM,IN	PWR DENSITY BTU/SEC/SQIN	EMISSIVITY
0.01642	0.01983	0.055921	1.857057	0.00060	0.0818	0.0476	0.2300
0.02158	0.02683	0.114976	4.683357	0.04000	0.1260	1.2584	0.2600
0.02858	0.03383	0.148226	6.266718	0.05320	0.1260	1.2508	0.2600
0.03558	0.04083	0.181477	7.850079	0.06640	0.1260	1.2463	0.2600
0.04258	0.04783	0.214728	9.433441	0.07960	0.1260	1.2433	0.2600
0.04958	0.05483	0.247978	11.016802	0.09280	0.1260	1.2411	0.2600
0.05658	0.06183	0.281229	12.600163	0.10604	0.1260	1.2400	0.2600
0.06358	0.06883	0.314479	14.183525	0.11925	0.1260	1.2388	0.2600
0.07058	0.07583	0.347730	15.766886	0.13250	0.1260	1.2382	0.2600
0.07758	0.08233	0.343622	17.350247	0.14567	0.1140	1.2370	0.2600
0.08408	0.08792	0.298794	18.820511	0.15794	0.0972	1.2365	0.2600
0.08917	0.09917		9.943509	0.00600		0.0889	0.2300
							0.0500

PLATE TEMPERATURES FOR ALL INCREMENTS, DEGREES R

INCREMENT NO.	1	2	3	4	5	6	7	8	9	10
1	4451.0	4459.2	4464.3	4468.7	4472.9	4477.0	4480.8	4484.5	4488.3	4492.0
2	4603.6	4659.8	4679.1	4690.2	4698.1	4705.4	4710.1	4714.3	4719.4	4722.7
3	4609.8	4669.3	4690.5	4702.6	4711.0	4717.7	4723.2	4728.2	4734.8	4737.9
4	4606.8	4666.1	4687.3	4699.3	4707.8	4714.5	4720.1	4725.1	4731.7	4734.9
5	4597.6	4657.0	4678.2	4690.2	4698.7	4705.4	4711.1	4716.1	4722.9	4726.0
6	4589.6	4649.0	4670.1	4682.2	4690.7	4697.4	4703.1	4708.2	4715.0	4718.2
7	4586.5	4645.8	4667.0	4679.1	4687.6	4694.3	4700.0	4705.1	4711.9	4715.1
8	4590.8	4650.0	4671.1	4683.1	4691.6	4698.2	4703.9	4708.9	4715.6	4718.8
9	4594.3	4652.6	4673.3	4685.0	4693.1	4699.5	4704.9	4709.7	4716.1	4719.0
10	4540.2	4596.1	4615.4	4626.2	4633.7	4639.5	4644.3	4648.6	4653.9	4656.4
11	4784.1	4336.5	4354.5	4365.0	4372.6	4378.7	4385.5	4389.0	4392.4	4395.8
12	3884.6	3888.4	3892.9	3897.5	3902.0	3906.6	3911.1	3915.6	3920.2	3924.7
13	734.0	734.1	734.2	734.3	734.4	734.5	734.6	734.7	734.8	734.9
AV FUEL TEMP	4515.8	4573.0	4593.3	4604.9	4613.0	4619.5	4625.3	4629.9	4635.9	4639.0
AV GAS TEMP	4390.6	4393.9	4397.2	4400.5	4403.8	4407.1	4410.4	4413.6	4416.9	4420.2
DIFF IN TEMP	125.2	179.1	196.1	204.4	209.2	212.5	214.9	216.3	219.0	218.9

STAGE AVERAGE FUEL TEMP = 4605.0 DEG R
STAGE AVERAGE OUTLET GAS TEMP = 4423.5 DEG R
STAGE AVERAGE OUTLET DYNAMIC HEAD = 12.4587 PSI

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COMPUTED TEMPERATURES AND PRESSURES. STAGE NO. 25

	PLATE TEMPERATURES			GAS TEMPERATURES		
	ENTRANCE	CENTER	EXIT	ENTRANCE	CENTER	EXIT
CENTER PLUG	4451.	4473.	4492.	4442.	4460.	4479.
FUEL RINGS	4604.	4698.	4723.	4485.	4501.	4517.
	4610.	4711.	4738.	4488.	4504.	4521.
	4607.	4708.	4735.	4486.	4498.	4513.
	4598.	4699.	4726.	4470.	4487.	4503.
	4590.	4691.	4718.	4464.	4480.	4497.
	4586.	4688.	4715.	4464.	4481.	4497.
	4591.	4692.	4719.	4473.	4489.	4505.
	4594.	4693.	4719.	4472.	4486.	4500.
	4540.	4634.	4656.	4357.	4367.	4379.
	4284.	4373.	4396.	3895.	3920.	3944.
RADTN SHIELDS	3885.	3902.	3925.			
CONTAINMNT SHELL	734.	734.	735.			

PASSAGE PRESSURE DROPS,PSF			MASS FLOW RATE			
FRICTION	MOMENTUM	TOTAL	LB/SEC-FT**2	PASSAGE WT FLOW,LB/SEC	EXIT MACH NO.	EXIT DYNAMIC HEAD,PSI
767.7	45.8	813.5	46.167	0.01792	0.1542	9.1562
634.0	55.6	689.5	54.510	0.04352	0.1832	12.9134
634.0	55.6	689.6	54.487	0.05609	0.1832	12.9121
633.7	55.9	689.6	54.541	0.06874	0.1832	12.9151
633.4	56.1	689.5	54.607	0.08143	0.1832	12.9191
633.2	56.3	689.5	54.650	0.09411	0.1832	12.9216
633.2	56.4	689.5	54.648	0.10673	0.1832	12.9212
633.8	55.5	689.3	54.597	0.11924	0.1832	12.9201
635.7	51.8	687.5	54.663	0.13203	0.1833	12.9365
667.2	46.1	713.3	53.627	0.12804	0.1769	12.1098
712.9	63.0	775.9	52.464	0.10876	0.1630	10.4242

STAGE END PRESSURE DROPS, PSF					TOTAL	REYNOLDS NUMBERS		
CONTRACTION		ENLARGEMENT			PRESSURE	ENTRANCE	CENTER	EXIT
FRICTION	MOMENTUM	FRICTION	MOMENTUM	TOTAL	DROP,PSF			
235.7	550.5	78.8	-565.4	299.2	1112.7	12938.	12911.	12877.
331.1	774.9	111.1	-796.8	420.2	1109.8	23374.	23330.	23276.
331.1	774.8	111.1	-796.8	420.2	1109.8	23353.	23310.	23255.
331.1	775.0	111.1	-797.0	420.2	1109.8	23405.	23360.	23305.
331.2	775.1	111.1	-797.2	420.3	1109.8	23465.	23420.	23365.
331.3	775.3	111.2	-797.4	420.3	1109.8	23505.	23460.	23404.
331.2	775.2	111.1	-797.3	420.3	1109.8	23504.	23459.	23403.
331.3	775.3	111.1	-797.3	420.5	1109.8	23451.	23408.	23354.
332.0	777.1	111.3	-798.3	422.1	1109.6	23482.	23445.	23398.
311.3	728.6	104.2	-747.3	396.8	1110.0	21209.	21181.	21139.
266.4	623.4	89.7	-643.4	336.0	1112.0	18060.	18000.	17934.

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INPUT DATA, STAGE NO. 26
STAGE POWER= 129.1 BTU/SEC
NUMBER OF RINGS=10
NUMBER OF SHIELDS= 1
STAGE LENGTH= 0.1250 FT.
ENTRANCE PRESSURE= 86742.6 PSF
HEAT LOSS= 2.2766 BTU/SEC

PASSAGE RADII,FT INNER	OUTER	F AREA,SQIN	S AREA,SQIN	RNG PWR DIST	EFF DIAM,IN	PWR DENSITY BTU/SEC SQIN	EMISSIVITY
0.01642	0.01983	0.055921	1.857057	0.00060	0.0818	0.0417	0.2300
0.02158	0.02683	0.114976	4.683357	0.04000	0.1260	1.1027	0.2600
0.02858	0.03383	0.148226	6.266718	0.05320	0.1260	1.0961	0.2600
0.03558	0.04083	0.181477	7.850079	0.06640	0.1260	1.0921	0.2600
0.04258	0.04783	0.214728	9.433441	0.07960	0.1260	1.0895	0.2600
0.04958	0.05483	0.247978	11.016802	0.09280	0.1260	1.0876	0.2600
0.05658	0.06183	0.281229	12.600163	0.10604	0.1260	1.0866	0.2600
0.06358	0.06883	0.314479	14.183525	0.11925	0.1260	1.0855	0.2600
0.07058	0.07583	0.347730	15.766886	0.13250	0.1260	1.0850	0.2600
0.07758	0.08233	0.343622	17.350247	0.14567	0.1140	1.0840	0.2600
0.08408	0.08792	0.298794	18.820511	0.15794	0.0922	1.0835	0.2600
0.08917	0.09917		9.943509	0.00600		0.0779	0.2300
							0.0500

PLATF TEMPERATURES FOR ALL INCREMENTS, DEGREES R

INCREMENT NO.	1	2	3	4	5	6	7	8	9	10
1	4486.8	4494.0	4498.5	4507.4	4506.0	4509.6	4512.9	4516.1	4519.4	4522.7
2	4620.3	4669.2	4686.0	4695.6	4702.5	4708.9	4713.0	4716.7	4721.1	4724.0
3	4626.2	4677.7	4696.0	4706.5	4713.8	4719.5	4724.4	4728.7	4734.5	4737.2
4	4623.4	4674.9	4693.1	4703.6	4710.9	4716.6	4721.5	4725.9	4731.6	4734.4
5	4614.7	4666.1	4684.4	4694.9	4702.2	4708.0	4712.9	4717.3	4723.1	4725.8
6	4606.9	4658.4	4676.7	4687.2	4694.5	4700.3	4705.2	4709.6	4715.4	4718.2
7	4603.9	4655.4	4673.7	4684.2	4691.6	4697.4	4702.3	4706.7	4712.5	4715.3
8	4607.8	4659.1	4677.3	4687.7	4695.0	4700.7	4705.6	4709.9	4715.7	4718.4
9	4608.1	4658.6	4676.4	4686.5	4693.5	4699.0	4703.6	4707.6	4713.1	4715.6
10	4547.8	4596.1	4612.8	4622.1	4628.5	4633.5	4637.6	4641.3	4645.8	4648.0
11	4299.7	4345.0	4360.6	4369.8	4376.4	4381.7	4387.8	4390.8	4393.8	4396.8
12	3931.2	3933.6	3937.3	3941.2	3945.3	3949.3	3953.3	3957.4	3961.4	3965.5
13	735.0	735.1	735.2	735.3	735.4	735.5	735.6	735.7	735.8	735.9
AV FUEL TEMP	4532.2	4581.8	4599.3	4609.3	4616.4	4622.0	4627.0	4631.1	4636.2	4638.9
AV GAS TEMP	4423.5	4426.4	4429.3	4432.1	4435.0	4437.8	4440.7	4443.5	4446.4	4449.2
DIFF IN TEMP	108.7	155.4	170.1	177.2	181.4	184.2	186.3	187.5	189.8	189.7

STAGE AVERAGE FUEL TEMP = 4609.4 DEG R
STAGE AVERAGE OUTLET GAS TEMP = 4437.0 DEG R
STAGE AVERAGE OUTLET DYNAMIC HEAD = 12.7230 PSI

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COMPUTED TEMPERATURES AND PRESSURES. STAGE NO. 76

	PLATE TEMPERATURES			GAS TEMPERATURES		
	ENTRANCE	CENTER	EXIT	ENTRANCE	CENTER	EXIT
CENTER PLUG	4487.	4506.	4523.	4479.	4495.	4511.
FUEL RINGS	4620.	4703.	4724.	4517.	4532.	4546.
	4626.	4714.	4737.	4521.	4535.	4549.
	4623.	4711.	4734.	4513.	4527.	4541.
	4615.	4702.	4726.	4503.	4518.	4532.
	4607.	4695.	4718.	4497.	4512.	4526.
	4604.	4692.	4715.	4497.	4512.	4526.
	4608.	4695.	4718.	4505.	4519.	4533.
	4608.	4693.	4716.	4500.	4511.	4523.
	4548.	4628.	4648.	4377.	4386.	4396.
	4300.	4376.	4397.	3944.	3967.	3988.
RADTN SHIELDS	3931.	3945.	3965.			
CONTAINMNT SHELL	735.	735.	736.			

PASSAGE PRESSURE DROPS, PSF			MASS FLOW RATE			
FRICTION	MOMENTUM	TOTAL	LB/SEC-FT**2	PASSAGE WT FLOW, LB/SEC	EXIT MACH NO.	EXIT DYNAMIC HEAD, PSI
774.4	43.6	818.0	45.788	0.01778	0.1556	9.1948
649.8	54.1	703.9	54.573	0.04357	0.1866	13.2095
649.9	54.1	703.9	54.550	0.05615	0.1866	13.2085
649.5	54.4	703.9	54.602	0.06881	0.1866	13.2112
649.3	54.6	703.9	54.666	0.08151	0.1866	13.2151
649.1	54.8	703.8	54.707	0.09421	0.1866	13.2176
649.1	54.8	703.9	54.705	0.10684	0.1866	13.2173
649.7	53.8	703.6	54.665	0.11938	0.1866	13.2179
651.7	50.2	701.9	54.772	0.13226	0.1867	13.2398
681.1	45.1	726.2	53.669	0.12807	0.1798	12.3469
723.6	60.2	783.8	52.053	0.10803	0.1649	10.5191

STAGE END PRESSURE DROPS, PSF					TOTAL	REYNOLDS NUMBERS		
CONTRACTION		ENLARGEMENT			PRESSURE	ENTRANCE	CENTER	EXIT
FRICTION	MOMENTUM	FRICTION	MOMENTUM	TOTAL	DROP, PSF			
236.3	553.0	97.1	-619.2	267.2	1085.2	12764.	12741.	12711.
338.6	792.4	139.3	-888.7	381.5	1085.4	23293.	23255.	23208.
338.5	792.3	139.3	-888.7	381.5	1085.4	23271.	23234.	23187.
338.6	792.4	139.3	-888.9	381.5	1085.4	23320.	23282.	23235.
338.7	792.6	139.4	-889.1	381.5	1085.4	23379.	23340.	23292.
338.7	792.7	139.4	-889.3	381.5	1085.4	23417.	23378.	23330.
338.7	792.7	139.4	-889.3	381.5	1085.4	23416.	23377.	23329.
338.8	792.9	139.4	-889.3	381.8	1085.4	23372.	23335.	23288.
339.7	795.0	139.6	-890.8	383.5	1085.4	23437.	23406.	23367.
317.3	742.5	130.2	-830.8	359.2	1085.4	21156.	21132.	21097.
268.9	629.3	111.0	-708.0	301.2	1085.0	17781.	17728.	17671.

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